A MANUAL OF PRACTICAL X-RAY WORK

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WITH ABOUT 120 ILLUSTRATIONS

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PREFACE

We offer no apology for publishing this small work on a subject which, though of recent introduction, threatens already to be somewhat overwritten.

From graduates attending post-graduate courses (chiefly Army and Navy surgeons) we learn that they have difficulty in finding a book to give them a practical understanding of radiology, with just enough detail to enable them to operate an ordinary installation.

To meet such want we have designed this work, and we trust that to medical students and practitioners it may serve as a sufficient introduction to the subject, and as a practical guide in working.

To apparatus we have been compelled to devote considerable space, for it is with that factor that medical workers, as a rule, find trouble, while an understanding of it is essential to successful working. But we have, as far as possible, confined our attention to *principles* of construction, without going into such details as are likely to alter in the natural course of development.

The chapter on 'Photography' should also meet a difficulty often felt by practitioners who desire to do their own radiographic work.

By request, we have included in Chapters III. and IV. sections dealing more in detail with the care and working of accumulators and of induction coils with the old vibrating or Nieve's hammer; this with a special view of meeting the wants of members of the profession in the Services.

Three things are necessary to give radiology that position of reliability in professional work which it is surely, but with difficulty, attaining—namely, good apparatus, intelligent and skilled use of such apparatus, and sound general medical training and experience to interpret and control the results so obtained. The two former conditions are possible enough

to operators outside the medical profession; the third is of its nature impossible to such persons, and the three cannot be efficiently separated. For a non-professional operator to offer medical opinion upon a radiogram is sheer impertinence, such as would be countenanced in no other profession or business; for a medical man to make an intelligent reading of a radiogram consonant with his earlier acquired medical knowledge, it is essential that he should thoroughly understand, and be in regular contact with, the production of such records. To such understanding we trust our work may contribute by forming a plain guide to a knowledge of the apparatus required, the methods of its operation, and the interpretation of the finished product.

Compilation we have purposely avoided, and the authorities indirectly influencing the formation of the opinions expressed are too numerous to acknowledge. Wherever possible we have quoted personal experience, and on that mainly is this work based.

Many questions in radiology are yet in an unsettled condition, many problems are only being freshly faced. Thus, 'instantaneous radiography' continues to attract much serious attention, and by adoption of suitable apparatus, results may soon be attained which will necessitate modification of certain views expressed by us on p. 103 (see p. 219).

Such points still under discussion we have purposely refrained from labouring, since this is meant to be in essence, as it is in name, *a practical manual.*

We are aware that we have omitted much which we might have noted or discussed, but we believe we have included all that is essential to an understanding of radiology, and we trust that what is lost through lack of elaboration may be more than compensated for by absence of confusion.

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INTRODUCTORY

To one already acquainted with radiology it matters little in what sequence we consider its various factors or problems. He will seek out for himself the parts in which he may be specially interested, or the points on which he may desire enlightenment.

As a general plan of the work, we have thought fit to begin by considering the immediate production of X rays; next to consider the remoter means of their production; then to proceed to the discussion of their practical uses.

For the benefit of those who have not previously studied the subject, we have sketched the following brief introductory note on **the evolution of the X-ray tube.**

Like so many other processes utilised by the medical profession, radiology is based on the results of painstaking research in pure science—research initially remote from any suggestion of therapeutic issue.

The present X-ray tube has been evolved from the older Geissler or vacuum tube. In the latter, when the pressure is reduced slightly, the resistance to electric discharge is lessened, and discharge takes place through the tube with striking phenomena of illumination, depending in character on the degree of exhaustion. The chemical nature of the residual gas also affects the character of the illumination; but we are concerned only with the presence of ordinary air. Exhaustion beyond a certain degree increases the resistance

to electric discharge through the tube ; and as the resistance increases, the luminosity of discharge disappears. But at a point of high exhaustion a fluorescence becomes evident on the walls of the tube, or on any object interposed between the electrodes. In vacuum tubes made of soda glass this fluorescence is of a transparent apple-green colour ; with lead glass it is of a bluish tinge.

Sir William Crookes, about 1891, studied and interpreted the phenomena of such discharge in high vacuum tubes, the

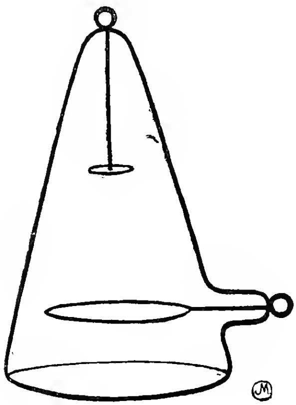


Fig. 1.

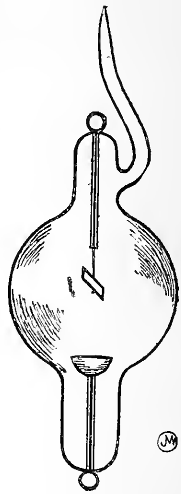


Fig. 2.

pressure in the tubes he worked with being reduced to about one-millionth part of an atmosphere. He shewed the fluorescence to be due to a bombardment of the interposed object by streams of negatively charged particles, moving from the kathode of the tube at a very high velocity. Such particles are now spoken of as electrons. In tubes such as were experimented on by Crookes these electrons are considered to move with a velocity equal to about one-tenth the velocity of light.

Lenard, working later with highly exhausted Crookes tubes, named this stream of electrons 'kathode rays,' and found that those rays also existed outside the tube. He

shewed that they could pass through some substances opaque to ordinary light, could excite fluorescence on suitable substances, and could act on sensitive photographic plates.

Roentgen, one year later—about the end of 1895—discovered that along with those kathode rays proper there were emitted by such high-vacuum tubes other rays having some differentiating properties. These he named X rays.

One essential physical difference consists in the failure of a magnet to deflect these X rays, whilst kathode rays are so deflected; nor can X rays be either reflected or refracted. Thus, in contrast to the kathode rays, which consist of what may be termed a corpuscular stream, X rays are true ethereal rays.

These X rays are produced by the impingement of the rapidly moving kathode rays on any obstacle in their path.

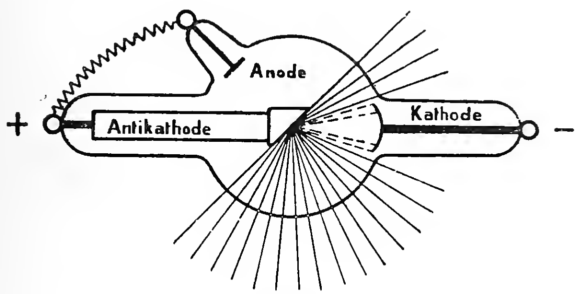


Fig. 3.

In the earliest tubes, as represented in Fig. 1, they were produced on the glass wall of the tube wherever it was struck by the rays proceeding from the kathode. That was in the form of a flat disc, whilst the anode was annular in form.

Herbert Jackson made important and essential alterations in design, and on his plan are constructed all X-ray tubes of the present day. The kathode was by him made of concave form, so as to focus the rays proceeding from it to the centre of the tube, and near that focal point was introduced a metallic target called the anode or antikathode. This target is set at an angle of 45 degrees to the axis of the tube, so as to throw the main part of the X rays to one side of the tube.

This device rendered the study and employment of X-ray effects much more precise, since the rays proceed from a definite point or small area of the target.

Fig. 2 represents the X-ray tube as designed by Jackson, the figure being drawn from an original model in the possession of one of the authors.

Fig. 3 represents diagrammatically the form of X-ray tube made at the present day.

Properties of X Rays.

Of the physical properties of X rays little need be said. The property upon which depends their use in medicine as a diagnostic aid is that of penetrating many substances opaque to ordinary light. The degree of penetration varies inversely with the density of the opposing substance. Thus, differentiated shadows are cast of the different tissues, and departures from the normal may be detected. Bone, being denser than muscular or other soft tissue, offers greater resistance to the rays; hence it casts a deeper shadow, and alterations in its density, as in necrosis, will influence the shadow cast, while such lesions as fracture will do so more markedly.

But to the naked eye X rays are not visible, and such interference with them not discernible; hence two other properties are brought into requisition—that of rendering fluorescent certain substances such as the platino-cyanides of barium and potassium, and that of acting upon sensitised photographic plates.

The intensity and differentiation of the shadow cast on a fluorescent screen by a certain radiation will depend upon the nature of the body or substance interposed between the screen and the source of the transillumınating rays; and so likewise will depend the image impressed on a photographic plate exposed for a suitable time.

The effect of X rays on living tissue exposed to them is discussed in the section on 'Therapeutics.'

CHAPTER I

THE X-RAY TUBE

Classification of Tubes.

Types and modifications of X-ray tubes are many and varied; but variations are of secondary import, and all conform to the general plan designed by Jackson.

As mentioned in the introductory remarks on the evolution of the X-ray tube, much depends on the degree of vacuum existing in the tube under observation. This vacuum, attained initially by means of a mercury pump, and completed usually by passage of electricity, can be adjusted within certain limits by the maker at the time of manufacture, and a tube may thus be made to suit any specified set of conditions.

A tube in which the exhaustion has not been carried very far is spoken of as of low vacuum, or '**soft**'; whilst a tube more thoroughly exhausted is by contrast of high vacuum, '**hard**,' or penetrative.

A **soft** tube, as compared with a harder one—

(1) Permits passage of an electric current with a **lower electro-motive force** (E.M.F.) in the tube circuit;

(2) Produces **greater quantity** of X rays;

(3) Emits rays which possess **higher actinic power**;

(4) Emits rays of **lower penetration.**

By **penetration** is meant the relative power of the rays produced to pass through objects interposed in their path.

Th s, rays from a soft tube will with difficulty penetrate bone; and if exposed to such rays the larger bones of the body will cast very deep shadows. On the other hand, a soft tube will reveal detail of structure in the smaller bones which

would be entirely undefined by the more penetrating rays from a hard tube suitable for viewing denser structures.

Thus the degree of vacuum, with its concomitant power of penetration, will indicate the value of a tube for any specified purpose, and results will depend largely on the judicious choice of a tube. It is well, therefore, to have in use several tubes of varying degrees of hardness, and to let each be reserved for uses suitable to its special powers.

Observation of Nature of Tubes and Quality of Rays.

The quality of the X rays produced is shewn above to depend upon the nature of the tube from which they are produced; hence it is very important to observe the nature of a tube during operation.

1. **The colour** in the tube, both of the fluorescent hemisphere in front of the antikathode and of the hemisphere behind that plane, varies according to the hardness; but this factor is too indefinite to give practical indication of other than gross differences. In a tube acting properly the hemisphere in front of the antikathode should show a bright apple-green fluorescence, while the hemisphere behind should be free from luminosity. In a soft tube the fluorescence is intensely green and uniform, while the gas in the tube shews a faint bluish luminosity plainly seen behind the antikathode. In a hard tube the fluorescence is thin and grey-green in tint, while irregular, flickering green spots are seen on the walls of the tube.

The penetration or penetrative power, dependent directly on the hardness, may be measured by several methods—

(*a*) By observing the **shadow cast on a fluorescent screen by a hand** interposed between that and the X-ray tube, the shadow cast by the bones approximating in density to that cast by the rest of the hand in direct ratio to the hardness of the tube. This is at the best but a rough, relative test, and is not to be recommended, as such repeated exposure of the operator's hand may lead to a serious dermatitis.

(*b*) By **radiometer** or **radio-chromometer**, an instrument made on the same principle as the tintometer

apparatus for estimating the hæmoglobin of the blood. In this the power of the rays to penetrate a metal of uniform density but varying thickness is observed and compared with a standard. The instrument of Benoist consists of a thin central disc of silver surrounded by a flat ring of aluminium graded by steps in thickness from 1 to 12 millimetres. For use, hold this up so as to intercept the rays from a tube, observe the shadow cast on a fluorescent screen, and note the sector or step by which is produced a shadow of density similar to that of the standard disc in the centre. The sectors being numbered according to their thickness, the higher

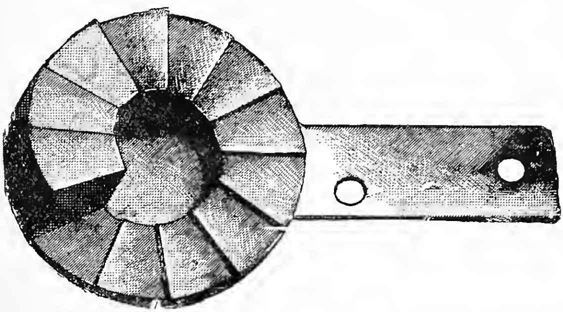


Fig. 4.—Benoist's Radiometer.

numbers will correspond to harder tubes. Modifications of this intrument have been introduced, some of them of value, but all are similar in principle.

(*c*) On the **equivalent spark-gap** more dependence in practical work is placed than on all other methods of indicating or estimating hardness or softness of tubes. When an X-ray tube is connected to an induction coil in the ordinary way, the discharge of the induced current may take place along two alternative paths, as is shewn diagrammatically in the annexed figure (Fig. 5). Discharge by way of the X-ray tube produces the special phenomena in the tube; discharge by the other path across the gap between the two discharging points of the coil takes the form of a series of sparks. The current in discharging will

always take the path of least resistance. The discharge-gap is variable at will by moving the points nearer or farther apart, and the resistance offered to discharge across these points will vary directly with the air-distance between them.

While a tube is in operation, if the points, at first far apart, be gradually approximated, a position will be reached at which discharge takes place through the air between the points in preference to passing through the tube. Conversely, if discharge is taking place across the points, and they are gradually drawn apart, then, after passing the above position, discharge will cease across the points, and will take place

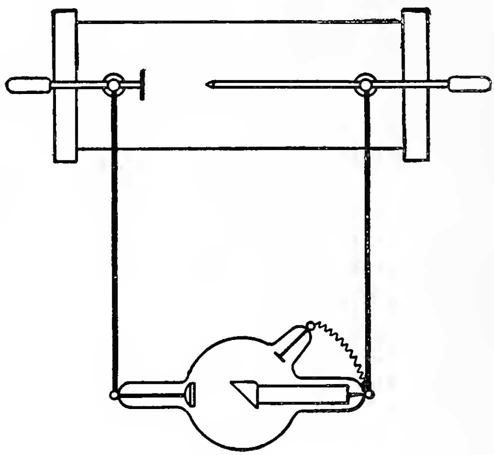


Fig. 5.

through the X-ray tube. This distance between the points, called the 'equivalent spark-gap,' or 'alternative path,' denotes the resistance and consequent nature of the tube.

In adjusting the distance between the discharge points care must be observed that the points are not allowed to come into direct contact, so as to make a closed circuit, for under such circumstances the induction-coil might be badly damaged by the heavy discharge of current permitted.

The arrangement is sometimes called a **spintermeter**, or **spark-measurer**, and the hardness of a tube is denoted by a number corresponding to the distance noted, which

distance is indicated on the sliding-rod of the discharge-gap. Thus, tubes with an equivalent spark of—

1 to 2 inches are **soft.**
3 to 4 inches are **medium.**
Above 5 inches are **hard.**

For purposes of comparison, it is necessary that the electrodes or discharging points of the spark-gap should be uniform in form and dimensions, since the same current will discharge across the electrodes at a greater distance apart if their opposing points be sharp than if they be rounded.

More uniformity in this is observed on the Continent, but all workers in this country should also adopt the standard of two spherical endings of 1 centimetre in diameter.

To prevent perforation, when using a hard tube it is well to leave the spark-gap only a little wider than the working distance of the tube. Otherwise, if the tube becomes too hard, there is no alternative path provided, and the current, if 'pushed,' will pass between the electrodes of the tube through the air outside, or seek a shorter path from the kathode to the outside by piercing the glass. This 'perforation' will destroy the vacuum, thereby rendering the tube useless, and repair is very difficult. If perforation occur, the tube will be seen to change rapidly and violet light to appear, while production of X rays entirely ceases.

Quantity of X Rays.

The quantity of rays produced must be taken into consideration as well as the quality, and depends on a number of factors more or less inconstant. These factors jointly determine the amount of electricity passing through the tube, and in direct consequence determine the amount of X-radiation produced. They include voltage and ampèrage of current supplied, periodicity and regulation of interruption, action of induction-coil, and nature of the X-ray tube. Most of these factors are under direct control of the operator, but in practice uniformity is difficult to maintain, and even with careful regulation variations occur. Also, as will be con-

sidered later, the X-ray tube may alter considerably in nature during a single operation.

Thus it is very difficult, from any or all of those initial factors, to estimate quantity of X-radiation, and time standards of exposure based upon them as data are unreliable. For long exposures for therapeutic purposes they may, indeed, be dangerous.

Only by noting the actual current passing at any moment through a tube in action, or by noting the actual effect, chemical or otherwise, of the rays produced, can one judge the quantity of X rays, and calculate their probable effect. None of our present methods of measuring the quantity of radiation or its effect are wholly satisfactory.

By watching the register of a **milliampèremeter** inserted in the tube circuit, the production of rays can for ordinary purposes be best measured, and the time of exposure for any desired effect judged. If this record tends to vary during the operation a time average may be taken, or by regulation of the current supplied to the induction-coil the amount passing through the tube may be kept constant. Since from a soft tube a relatively greater quantity of rays is produced, it is of importance to observe any softening of the tube during exposure. This is of special importance in therapeutic work, since therapeutic action seems to depend for its intensity directly on the quantity of radiation in the exposure. This change, corresponding to a fall of electric resistance in the tube, will be indicated by a rise in the reading of the milliampèremeter, and, conversely, hardening of the tube will be indicated by a fall in the reading.

Where a maximum therapeutic effect is desired at one exposure, as for epilation in treatment of ringworm, it is pre-eminently important that the degree of exposure should be carefully measured, for the margin of safety between epilation and a serious dermatitis is narrow. For this purpose **Sabouraud's pastilles** are very serviceable, though by no means deserving to be considered as a final standard. These are exposed to the rays during the actual exposure, and by chemical change directly measure the quantity of radiation and indicate the probable therapeutic effect. Con-

sisting of platino-cyanide of barium, thickly coated on small discs of paper, the pastilles on exposure to X rays alter in colour from a canary-yellow to a brown. The change is proportional to the cumulative effect of the exposure. Thus, by comparison with a standard tint the operator can determine from the pastille when the desired degree of exposure has been reached. The conditions to be observed in using these pastilles will be found described in the section dealing with therapeutics (p. 233).

At the meeting of the British Medical Association at Exeter a meter was described which registered the electrolytic effect of the current passing in the tube circuit. The effect is, of course, cumulative, so that the amount of gas liberated and measured in a eudiometer tube will bear a direct ratio to the current which has effected its disassociation. This is a very ingenious device, and well merits attention; but, for maximum exposures, we feel that we should like to understand more fully the vagaries of X-ray tubes before we depend on any other measurement than that directly made of the actinic effect of the radiation in question.

Changes in X-Ray Tubes by Use.

I. **By repeated use** an X-ray tube becomes progressively **harder.** This is due to (*a*) **inverse currents**, and (*b*) **escape**, or occlusion of gaseous particles from the interior of the tube.

(*a*) The formation and prevention of **inverse currents** are discussed later, when induction-coils fall to be considered. Meanwhile, we note that inverse currents may originate in the secondary winding of the induction-coil, and pass through the tube as discharge in a reversed direction. In their passage these currents tear from the platinum antikathode fine particles, which absorb or occlude electrons from the rarefied contents of the tube and thus increase the degree of vacuum. Presence of such inverse currents may be noted in the action of the tube, since they produce a flickering of the fluorescence, specially noticeable in the hemisphere normally dark.

Due to this action, the fluorescent hemisphere of a tube, subjected to such adverse influence, becomes blackened by deposit of finely disintegrated metallic particles, in contrast with the violet tint due to chemical change acquired by a tube guarded from inverse currents. To obviate disintegration during correct operation of a tube, the kathode is generally made of aluminium, which is found to resist such action more than any other metal tried.

(*b*) **Escape of electrons** may occur by piercing the glass of a tube, impulse from within being so much greater than any pressure from without. The degree of vacuum in the tube is thereby directly raised.

II. **During each operation** there tends to be (*a*) a **progressive softening**, or, under exceptional circumstances, there may be (*b*) a **slight hardening**.

(*a*) A progressive softening is noted when a tube is so operated that the antikathode becomes overheated by the continual bombardment of the kathode rays. This heating has the effect of liberating electrons otherwise held bound by the metal, and by the liberation of these into the space of the tube the degree of vacuum is lowered.

If the tube be over-driven, this effect may become so marked as to reduce the equivalent spark-gap to nil. In operating a tube, its condition should be observed periodically by approaching the discharging points of the coil or noting the reading of the milliampèremeter. If softening of the tube be indicated by a marked shortening of the alternative spark-gap, or rise in the reading of the milliampèremeter, care must be observed that the tube does not receive injury, or the patient be exposed to risk of over-effect. In such event it will be well to decrease the amount of current employed or to give the tube time to cool.

In use the antikathode should never be allowed to get hotter than indicated by a cherry-red colour, unless softening of the tube is desired for special photographic effects, as will be described later.

If the kathode rays were focussed to an actual point on the antikathode the metal would readily become fused by the heat. Therefore in practice the target, made of platinum, is placed a little to one side axially of the focal point, and the X rays originate from a small circular area measuring between $\frac{1}{16}$ and $\frac{1}{8}$ inch in diameter. To permit of a nearer approach to the true focus, combined with prolonged use, it has been suggested to make the target of osmium or iridium on account of their greater hardness and infusibility, but the expense and trouble in working of those metals are incommensurate with the advantage to be gained by their use. This point is further discussed later (p. 20).

The focal area on the target is usually indicated by a slight roughening of the metal, the test-running by the maker being sufficient to produce this effect, and it should be looked to in selecting a tube. If larger than $\frac{1}{8}$ inch in diameter, there will be lack of definition in shadows cast by the tube.

(*b*) **Slight hardening** of the tube may occur, or softening process be delayed, by the presence near the tube of an insulated mass of metal such as in a diaphragm. Such metal acts as a condenser, and, holding electrons bound to the adjoining inner surface of the tube, reduces the number free to occupy the tube space, and thereby raises the degree of vacuum. This effect may be obviated by connecting to earth either the kathodal wire or the metal mass in question.

Modifications of X-Ray Tubes.

I. **Addition of a third electrode** is one of the earliest and most common modifications of the tube from the form designed by Jackson. This serves as an anode, placed axially opposite to the kathode, and is connected outside by a wire to the target antikathode, the stem of which passes through the tube wall in a line at right angles to the desired plane of the target.

This arrangement is said to steady the action of the tube

in a manner variously explained, and also to prolong its working life by retarding the change in quality described above, but its service is questionable. In France and America it seems to be little used, though in the German pattern of tube, which is mainly followed in this country, it is almost universal.

II. **A larger diameter** is given to tubes than formerly, changes temporary and permanent being thus delayed, and the life of the tube prolonged. Originally tubes of 2½ inches in diameter were commonly used; now 5 or 6 inches is a common diameter; whilst tubes are made of 9 or 10 inches diameter, and may become more general.

Before choosing a tube of large diameter, however, one must ascertain whether the internal electrodes of the tube are

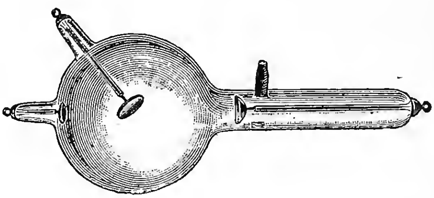


Fig. 6.

set correspondingly farther apart, for this distance may be limited by the power of the coil employed. With a small coil —say a 10-inch size—a tube with electrodes set far apart might soon become too resistant for the full power of the coil to excite, while a tube of smaller proportions under similar circumstances would permit excitation and emit rays of sufficient penetration for all purposes.

With tubes of proportions as ordinarily made we would suggest that—

With a 10-inch coil, a tube be used of 13 centimetres or 5 inches in diameter;

With a 15-inch coil, a tube be used of 15 centimetres or 6 inches in diameter.

With static machines smaller tubes are more serviceable, one of 8 centimetres or 3 inches diameter giving useful penetration.

Of course, makers could construct larger bulbs while maintaining the shorter distance between the electrodes; but the two dimensions usually vary in proportion, hence the above caution should be remembered.

III. **A vacuum regulator** of some kind is added to almost all modern tubes, except the very low-priced ones. Such an addition is an ultimate economy, since it counteracts the hardening effect of continued use, and thereby prolongs the period of usefulness of the tube.

These regulators, when brought into action, give off, or transmit, gaseous substance, whereby the number of electrons in the interior of the X-ray tube is increased, and the degree of vacuum correspondingly reduced. They are set in action by heat, produced either by electric discharge or by direct application of a flame to the regulator.

(*a*) A small **side-tube containing a chemical** (such as KHO), which **gives off vapour** when heated, may be attached in construction to the X-ray tube. When desired, this is heated by a flame applied to the outside, and gas is thereby driven off, which passes into the main tube. This early form is now superseded by more convenient arrangements, but illustrates the elementary principle of such regulators.

(*b*) **A side-tube with some capillary substance**, such as woven glass, mica discs, asbestos, or spongy metal, may be similarly connected to the main tube, as shewn in Fig. 7. The capillary substance is arranged at one end of the side-tube, and is traversed or surrounded by a platinum electrode, to which, when put in circuit, sparks may discharge from an electrode in the form of an aluminium disc at the kathode end of the tube. By such discharge heat is generated, and the gaseous contents of the capillary substance are thereby caused to expand, and part to be expelled into the vacuum of the larger tube.

(*c*) **Automatic action** of such regulators as the above may be attained by affixing to the aluminium electrode one end of a stiff wire, and arranging the other end of this wire at a suitable distance from the kathode of the

X-ray tube, as shewn in Fig. 7. Then, when the tube becomes of a certain degree of hardness, thereby offering greater resistance to discharge than is desired, sparks will pass from the kathode to the wire, and thence current will traverse the side-tube. There electrons will be liberated, till by their presence the vacuum of the main tube is reduced to the point at which discharge takes place through it in preference to jumping the arranged air-gap between the kathode and the side-tube wire.

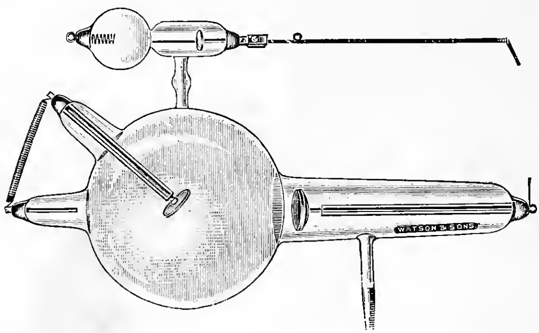


Fig. 7.

This is a very convenient arrangement if carefully used, but the utility of all such regulators depending upon a pre-existent supply of occluded gases is limited. For after some time all the available gas has been expelled from the capillary spaces, and there is no means of renewing the supply. Hence the regulator ceases to be of further service.

(*d*) **Osmo-regulators** do not depend upon any such limited supply, and are therefore preferred by us for any tube in continuous working. These regulators depend upon the property of certain metals becoming, when heated, permeable to hydrogen, the property of so-called selective 'osmosis.'

A slender, thin-walled tube of one of those metals, closed at the outer end but open at the inner, is sealed through the glass wall of the X-ray tube, so as to project

a short distance into the tube and for about 2 inches outside. This may form part of the anode, as shown in Fig. 8A or 8B, or be sealed into a projecting side-piece of the tube, as in Fig. 9. On the projecting part of the regulator being heated by the flame of a spirit-lamp or Bunsen burner, hydrogen gas passes into the interior of the tube

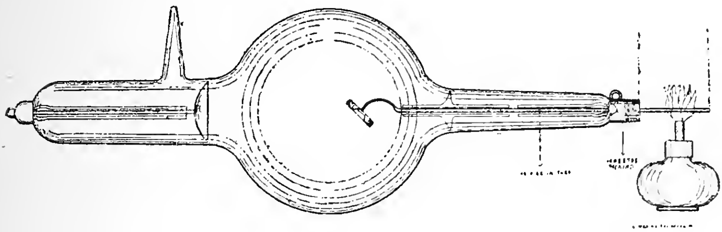


Fig. 8A.

and by addition of its electrons lowers the vacuum as desired. The metal employed must possess the same coefficient of expansion with heat as glass, otherwise the sealing would be impossible; but fortunately such metals are procurable.

Platinum is the metal commonly employed, but its action is somewhat slow. Palladium, on the other hand,

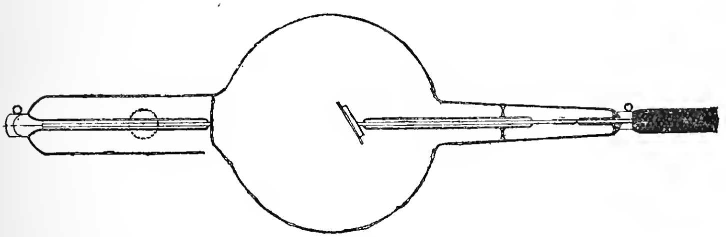


Fig. 8B.

is too sensitive, and the process is difficult to regulate where it is employed. A compound of the two metals has been recently tried, and gives very satisfactory results with careful working.

These metal regulator tubes are very easily damaged, and should always have screwed over them a protecting

cap, as shown in Fig. 8B, which should be removed only when it is desired to excite the regulator.

An X-ray tube should be fairly soft when new, and should never be allowed to become very hard, but by a brief excitation of even a slow osmo-regulator at frequent intervals, it should be kept in good working condition.

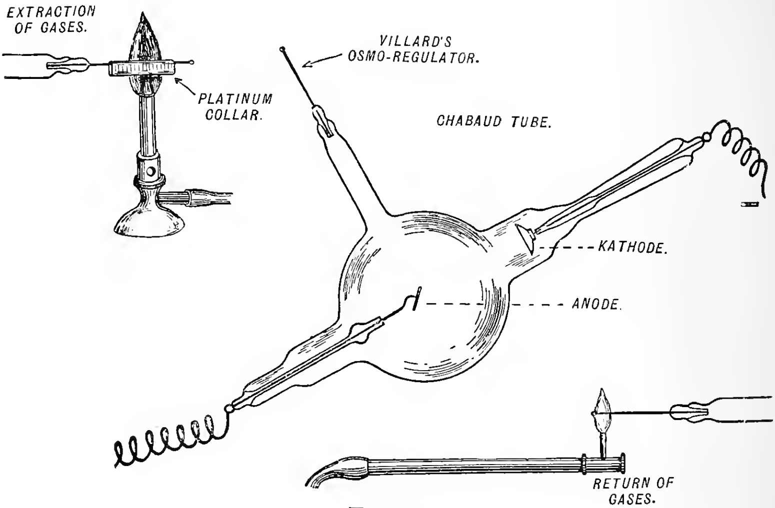


Fig. 9.

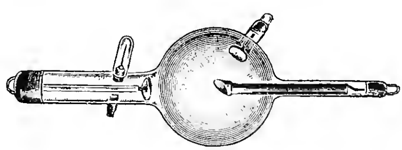


Fig. 10.

IV. **Means to prevent over-heating of the antikathode** are various:

(*a*) **Heavy metal** antikathodes, as in Gundelach's tube, illustrated here, serve well, the increased mass of metal taking much longer to become injuriously hot than the ordinary thin discs employed. For the first twenty or thirty excitations such tubes are disappointing, since

they soften rapidly, and to a marked degree. This is due evidently to the occluded gases unavoidably present in the metal, but after a time these become exhausted. Then the tube works steadily, and will stand long runs with heavy currents very satisfactorily.

We would suggest that a new tube of this type be used for therapeutic purposes for a time, its condition being carefully noted meanwhile before reliance is placed on it for radiographic work.

(*b*) **Water-cooled** tubes have the antikathode and stem surrounded by a water-jacket, which retards the heating

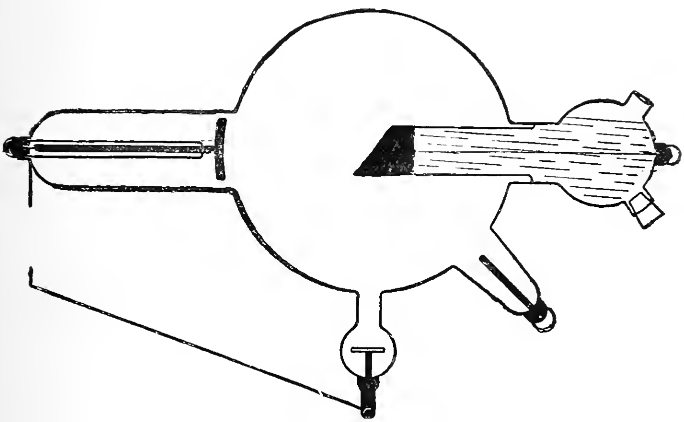


Fig. 11.

of the target. Special attention must be paid to the position of the tube, so as to have the water in the jacket always in contact with the target. Thus the range of use of such tubes is limited. Fig. 11 shows in diagram a design allowing adjustment of plugs to suit the position of the tube.

(*c*) **Air-cooled** tubes of similar principle are a recent modification, and, in our experience, seem to be a very efficient arrangement for the purpose, being very constant in action and capable of being used in any position. Their price is so far somewhat prohibitive for ordinary use, and more experience of their working is desirable

before finally judging them. A good example of this tube is the 'Tantalum,' as shewn in Fig. 12A.

V. The **metal parts** have been modified in various ways, as mentioned earlier, to avoid disintegration and damage from over-heating. Since the main cost of a tube is in the labour of manufacture—and this is the same for whatever material be employed—it is obvious that the best suitable material should be insisted upon in all tubes, however their design or construction may be modified to lessen their price. The **purity** of metals employed is of prime importance,

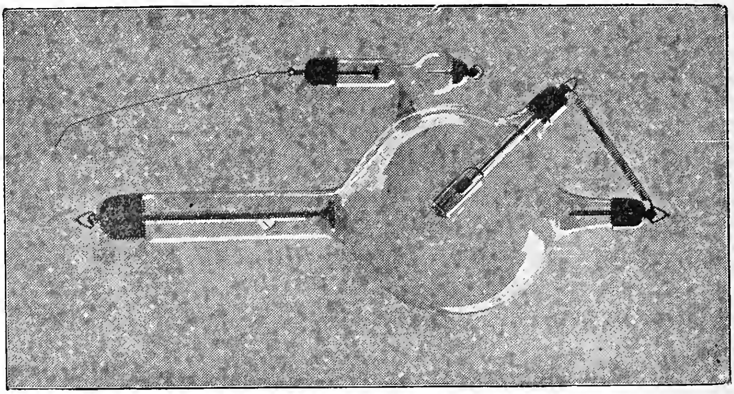


FIG. 12A.

especially in the case of the **kathode** and its supporting stem, for which **aluminium** has proved to be pre-eminently suitable.

Much of the value of a tube depends upon the construction of the **antikathode**, since the quality of the resultant radiation seems to depend largely upon the 'stopping power' of the material opposed to the kathode rays. Probably in no case are the kathode rays all stopped by their first impact on the surface molecules of the target, but some rays penetrate to deeper molecules before being stopped and giving origin to the resultant X rays. Thus radiations are produced, as it were, from successive rows of molecules; and this would seem to explain the origin from one tube of a collection of rays of differing qualities. Those rays produced by the

stoppage of kathode rays at the first row of molecules are of the highest degree of penetration, and probably also actinic effect. **Platinum**, of all the metals tried, possesses the highest stopping power, and the heavy anodes of pure platinum employed in some of the most expensive tubes give beautiful effects. But pure platinum is very liable to overheat, and probably the best all-round antikathodes are now made of **platinum** alloyed with a proportion of pure **nickel**, thus combining stopping power with resistance to overheating.

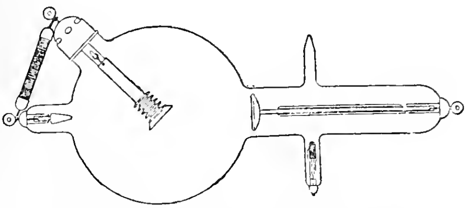


FIG. 12B.—AIR-COOLED X-RAY TUBE.

Methods of Altering Nature of Tubes.

I. **Softening** may be necessary to utilise an old tube, or to adapt any tube for a special purpose requiring a lower degree of penetration. This may be effected in various ways:

(*a* **Use of regulators,** as described above, is the **preferable method.**

In the absence of a regulator—

(*b*) **Baking** the tube for some hours in an oven at a high temperature may somewhat soften a tube permanently.

(*c*) **Laying the tube aside** for a year or more induces some degree of softening.

(*d*) **Heating the tube** carefully, by the flame of a spirit-lamp or before a fire, softens it **temporarily,** but on cooling the previous hardness is reassumed. A tube may be thus softened while in the live circuit (that is, with current passing, or tending to pass, through it). Thus natural softening may be hastened, or the vacuum initially reduced, to allow discharge through the tube to commence. In such a case the

spirit-lamp employed should be held on a long insulating handle, so as to protect the operator from shock or X-ray burn. Care must be taken in so heating a tube that no part is over-heated, as a dent may be readily produced in the softened glass by the atmospheric pressure outside acting against the much-reduced pressure within.

All softening processes should be carefully regulated, and must not be carried too far, since hardening is difficult, and always more or less injurious to the tube.

II. **Hardening** should never be called for where a graded stock of tubes is kept as advised, and where due care is exercised in use of the tubes or in any softening process called for. Where under special conditions hardening may be necessary, it is best done by—

(*a*) **Sending the current through the tube in the inverse direction** for a short time, the effect being similar to that described as causing the gradual hardening of tubes through continual use.

(*b*) **Villard's method**, by heating an open tube or sleeve placed over an osmo-regulator, whereby the ordinary softening function of that arrangement is said to be reversed and hydrogen drawn out of the tube, is unsatisfactory in practical use. This method is illustrated in Fig. 9.

(*c*) The automatic **side-tube regulator**, represented in Fig. 7, is also said to be available for the purpose of hardening. To do so, it is advised to remove the positive wire from the anode of the X-ray tube, and to connect it to the terminal at that end of the side-tube, the negative wire being connected to the kathode terminal as in ordinary excitation of the X-ray tube. The side-wire of the regulator must be well separated from the kathode terminal, and current then passed through. We have not used this method frequently, nor do we recommend it.

On the rare occasions on which hardening has been called for, we have found the first-mentioned method the most serviceable.

CHAPTER II

SOURCES OF SUPPLY

The source of supply of electricity for X-ray work may be one of a number of varying description.

The work to be done will dictate the choice where that is an open one; but more often the choice will be dictated by the factors of convenience and economy relative to the installation under consideration.

Undoubtedly the best method presently available for all-round work in this country is to employ a continuous current of 50 to 100 volts, and to convert that to the high potential necessary to operate an X-ray tube by passing it through an induction-coil.

We are aware that in America the static machine is the favourite source of supply, and we believe that with some alterations in construction, likely to be introduced at an early date, that machine will find increasing favour in this country, where climatic and other conditions render its use somewhat uncertain in its present forms. The tendency of modern workers to employ softer tubes will also encourage this change.

Where a supply already exists in some way different from that here recommended, we believe that it is always most satisfactory to convert it into that form.

This may mean initial expense, but, where any serious amount of work is to be done, that will soon be compensated for in convenience and economy of working.

The various sources of supply ordinarily available are:

I. **The main.** This is the most satisfactory source, and may be (1) **continuous**, (2) **alternating**.
II. **Accumulators.**
III. **Primary batteries.**
IV. **Dynamo machine.**
V. **Static machine.**

I. The Main.

1. **Continuous current from the main,** where available, should certainly be used direct for any permanent installa-

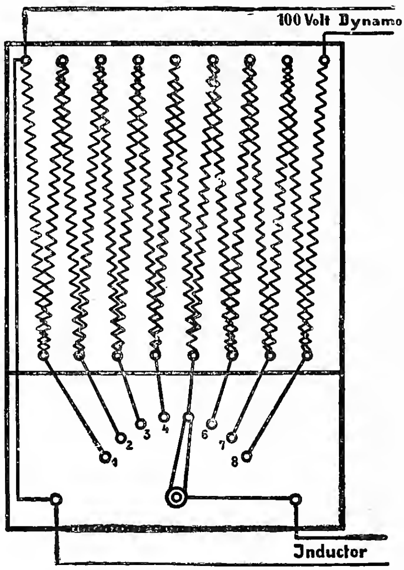


Fig. 13.—Diagram of Shunt Resistance, arranged in Circuit of 100-Volt E.M.F.

Current to the inductor or coil will decrease as the crank is moved over the studs towards the left. Each of the sixteen spirally coiled wires may be taken to represent a fall in potential of $\frac{1}{16}$ of the maximum voltage—in this case 100 volts. Thus the available voltage at any stud of the eight may be easily calculated. The crank in figure makes contact with the fifth, at which the available voltage will be $(100 \times \frac{9}{16}) = 56$ volts.

tion. If at a voltage of 100 or less, the current may be sent unaltered to a suitably-designed interrupter and coil. If at a higher voltage (as in West London, where voltage is 240), some form of modifying apparatus must be interposed. In

this country the usual supply from the mains is continuous, at a pressure of 200 to 250 volts.

(*a*) A **rheostat** in some form may be introduced, whereby current at any voltage in a regular series may be used as desired. The usual form consists of a number of open coils of thick iron wire, suitably fixed to a slab of slate or marble, and connected, as shewn in Fig. 13, so that any length may be introduced as resistance in

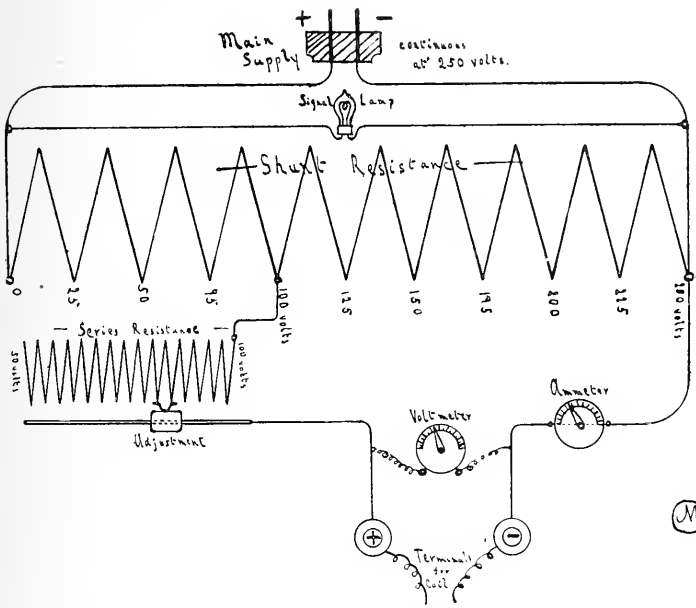


Fig. 14.—Combined Shunt and Series Resistance, on Continuous Main at 250 Volts.

the circuit. This piece of apparatus, from its function, is often termed a 'volt selector.' Its principle may be understood from the annexed diagrams (Figs 13 and 14). In '**direct**' resistances the current is directly 'choked off' before reaching the further parts of the installation, as in the smaller coil shown in Fig. 14. In a '**shunt**' arrangement, as shown in Fig. 13, and in the larger coil of Fig. 14, an alternative path is offered to the current, and more or less of the available current passes by this

alternative circuit as more or less resistance is introduced into the installation circuit, which receives current inversely proportional to the resistance. This latter form is preferable, as the transition is rendered more smooth and gradual between adjoining steps of the selector. In both instances the residue of current disappears in the resistance, being spent in the production of heat in its coils. Thus such an arrangement may appear wasteful of current; but it is really more economical than an individual supply for the relatively small quantities usually required, and current is supplied from the main for such purposes at reduced rates.

Fig. 14 shows diagrammatically a very convenient arrangement, whereby a high voltage (say 250) is first adapted by a shunt resistance to 100 volts, then current selected as desired from a series resistance giving a range from 100 to 50 volts.

(*b*) A **motor-transformer** is probably more economical where larger quantities of current are likely to be used, as in regular hospital work. This piece of apparatus, as shown in Fig. 15, consists of a motor constructed to run at the voltage of the main supply, and connected direct to a dynamo wound to give off current at the voltage desired for use. In our opinion, **50 volts is the ideal strength for general X-ray work**, since it is sufficient for all practical purposes; and disturbance in the induction-coil is obviated from the inverse currents, which at higher voltages become of sufficient magnitude to be troublesome.

A motor-transformer is extremely easy of manipulation, and, beyond ordinary care of lubrication and attention to brushes of the generator, requires no attention, expert or otherwise.

The starting-switch is usually made of a form to send the driving current into the motor gradually, since the full current, suddenly switched on to the motor winding, might readily do serious damage to it. In ordering this piece of apparatus, the voltage of the supply must be noted, as well as the nature of the current desired to be generated for use.

2. **Alternating current** is unsuitable for direct use, and must of necessity pass through some modifying apparatus before reaching the X-ray installation.

(*a*) A **motor transformer** is, in our opinion, the most satisfactory means of adaptation, the motor being wound to drive off the alternating circuit, and being coupled direct to a dynamo designed to supply continuous current as desired. In the West London Hospital the current supplied from the main is alternating, at 110 volts, with a periodicity of 50 per second. This is led to a $2\frac{1}{2}$ horse-power motor-transformer, from which

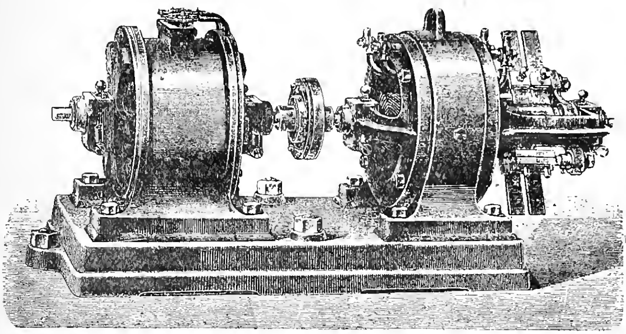


Fig. 15.

continuous current is derived at 50 volts, with a maximum of 20 ampères, for use in the X-ray department.

The above note and figure on motor-transformers for converting the voltage of continuous current from the main apply equally to those designed for converting alternating current. In this case it is necessary, in ordering, to state the voltage of supply, its period, and its phase—single, triphase, etc.

(*b*) The **Gaiffe-Blondel mercury jet break,** shewn in Fig. 16, is an example of a type of machine designed to work synchronously with the period of an alternating current, and so transmit the impulses in one direction, while arresting, or diverting, those in the other. This

action produces an interrupted unidirectional current suitable for supply to an induction-coil. But, in our experience, though this arrangement is good for high-frequency or for therapeutic work, the synchronicity may occasionally fail. Thereby the polarity of the resultant current may become reversed, and the irregular rays thus produced in an X-ray tube spoil an exposure

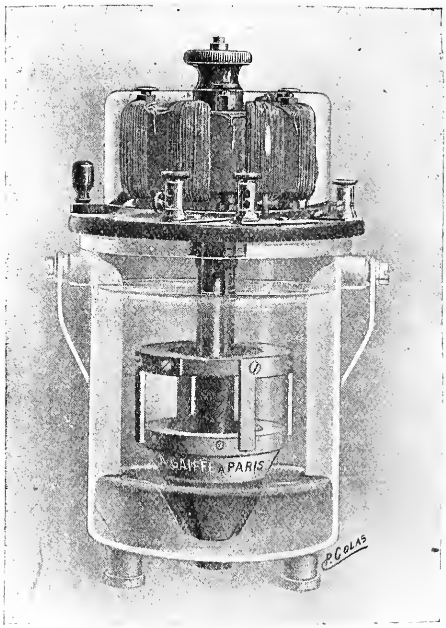


Fig. 16.

for radiographic purposes. Along with a Villard's valve-tube to protect the X-ray tube from such inverse currents this break may, however, form a satisfactory means of utilizing an alternating current.

(*c*) **Nodon's valve,** or **aluminium cell,** is a simple and valuable device for utilizing alternating currents for medical purposes, since it has no moving parts and requires little attention.

Such a cell consists of an active electrode of aluminium,

immersed in a suitable solution (in some of common salt, in some of ammonium phosphate), along with an indifferent electrode of lead, carbon, or iron; the containing cell in many designs supplying the latter. The action of the cell depends upon the peculiarity of aluminium that as kathode it allows a current to pass freely, but as anode it offers high resistance. This resistance is due, doubtless, to polarisation, whereby a thin, insulating film of oxide is formed on the surface of the metal. The other phase or direction of current easily breaks through this, but up to a certain voltage the cell automatically allows only that phase to pass.

By suitable combination of cells, explained later, both phases may be utilised, and a pulsating unidirectional current obtained from an alternating supply.

Heating of the liquid will interfere with the efficiency of a cell if the temperature rises above 70° F.; but short of that those cells may do a lot of heavy work, especially if arranged as advised on p. 43, and shown in diagram there.

For X-ray work the current produced is not satisfactory, either led direct to the coil or passed through an interrupter.

For **charging accumulators** from an alternating main, however, these cells work very satisfactorily. In the note on accumulators already referred to will be found a description of the arrangement.

In our hospital work this was the original plan adopted, and it served fairly well for about two years, until pressure of work induced us to discard it for the less troublesome plan of a motor-transformer.

Fig. 17 represents a set of cells as manufactured for sale, but efficient cells may be made very cheaply by anyone willing to take a little trouble. For description of such a cell and other practical points, see p. 42.

(*d*) **Electrolytic interrupters** are said by some to work satisfactorily with alternating current, preferably with an aluminium cell in series. The nature and use of this type of interrupter is described later on p. 58, and we highly commend it under suitable conditions; but we do not consider an alternating main one of those conditions.

(e) A number of other so-called '**rectifiers**' have been designed to render an alternating current unidirectional, but in our experience none of those have proved of practical value.

II. Accumulators.

[*By request* we have in the following section dealt with accumulators in more detail than with most of the other apparatus, so as to furnish a guide in their practical application.]

Accumulators are valuable as sources of direct supply—

(1) Where portability is of prime importance;

(2) Where there is an existent source of supply, but not convenient for direct connection by wiring to the X-ray installation;

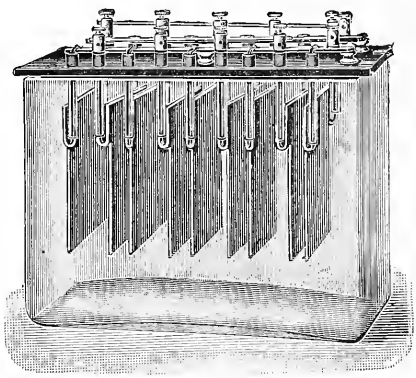


Fig. 17.

(3) In occasional cases where supply is available, but not of a nature for direct use.

1. Where an X-ray outfit is chosen mainly with a view to **portability,** the advantage of accumulators will depend largely upon convenient opportunity of recharging them, since they can by no means be made to produce electricity unless in the degree to which that has been previously supplied to them.

Elsewhere in this chapter (pp. 46 and 47) we suggest possible arrangements of a portable nature where the set must be self-

sufficient for all purposes. With such apparatus for primary production of electrical energy, it will probably be advantageous in many cases to combine the use of accumulators. These may be periodically charged from the primary source, and kept in readiness for immediate use at any time; whereas it may be inconvenient to bring the generator into action when current is required.

For bedside work accumulators are ordinarily the only source of supply worthy of consideration, though the advent of a portable form of static machine would alter the definite character of this statement. The method of charging accumulators for such use will depend upon local conditions of the operator.

2. In the **absence of a convenient direct supply** for a permanent installation, accumulators may be used after being charged elsewhere; but if much work is to be done, it is better, in our opinion, to instal some form of generating apparatus to provide a direct supply. This may be understood when we come to speak of the process of recharging accumulators, for, if a primary source be inconvenient, then the chances are that the accumulators will not be recharged so frequently or regularly as they ought to be in order to preserve their efficiency. Under such circumstances, also, transport of the accumulators renders this a troublesome and costly method for regular working. Here again, however, the use of accumulators may be combined with the installation of a primary source of supply, where that may be more conveniently or economically brought into action only at periodic times.

3. Where a **supply** of any nature is **available intermittently,** accumulators are eminently serviceable to render the energy available as it may be required.

For **conversion** of an unsuitable regular supply accumulators may prove of service, as in the method, for a time employed by us to utilise an alternating current, described on p. 44.

In most cases we think some of the other means suggested will prove more commendable, but each case must be considered in relation to its own special conditions.

Usually, where the use of accumulators is indicated, it will

be necessary for the X-ray worker to superintend their recharging, and to see personally that they are maintained in a state of efficiency. This personal responsibility may be obviated if the cells be sent to an electrician, or to a generating-station, where expert attention may be expected; but such, as we have said, is a most inconvenient and costly mode of working. Further, it is very frequently under circumstances which render it impossible to obtain expert assistance that accumulators will be found most useful.

The operator being thus directly responsible, we have, on request, decided to enter more fully into the questions of charging and working accumulators than into most of the other details dealt with in this small work. For men in army or navy service we trust this will be especially useful.

Accumulators are often spoken of, somewhat loosely, as 'storage cells' of electricity. This they are in effect, for, after receiving an appropriate 'charge' of electricity, they may be kept for some time, and thereafter a 'discharge' of electricity obtained from them; but the term is misleading. More properly they might be termed 'energy transformers,' or storage cells of energy. An electrical current, passed through an accumulator cell, produces chemical changes in the constituents of the cell, which thereafter stores energy in a potential form, represented by the force impelling the constituents to return to their former condition.

An external circuit being completed between the terminals of the cell so charged, its constituents more or less gradually resume their former condition, and the potential energy thus liberated appears in the form of electrical effects in the circuit.

The chemical changes referred to are somewhat complicated, and we do not here attempt a full explanation.

Each cell (as shewn in Fig. 18) contains several lead plates, connected alternately to the positive and negative terminals of the cell; and all are immersed in, and well covered by, dilute sulphuric acid.

During charging, a current of electricity is sent through the cell from a suitable source of supply. By electrolytic action there are produced from the acid quantities of free

oxygen and hydrogen. The former appears on the plates connected with the positive pole, converting them gradually into peroxide of lead; whilst the hydrogen appears on the negative plates, reducing them to a porous, spongy mass of metallic lead. Those actions on the lead plates having proceeded as far as possible, the gases escape in bubbles from the liquid, thereby indicating the completion of the charging process. In discharging, those processes of oxidation and reduction are reversed; the plates return to their previous condition, and the acid regains its original strength.

Thus the process may be repeated any number of times in the same cells, if due precautions be observed.

Some of those precautions we will now discuss, before

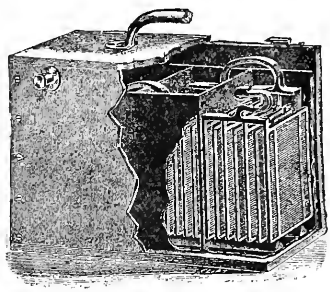


Fig. 18.

describing the methods of charging accumulators from various sources of supply.

Accumulators for X-ray work are generally arranged with four cells in each box, as in Fig. 18. The cells are connected in series—that is, the negative pole of one is connected to the positive pole of the cell adjoining it, leaving at one end of the box a free positive terminal, and at the other a free negative terminal. The E.M.F. of each cell being fully 2 volts, such a box of four cells will give, when fully charged, at least 8 volts. Three such boxes are as a rule employed, thus obtaining an E.M.F. of 24 volts for use.

The number of plates varies, but in each cell of those we use (as in that shown in Fig. 18) there are seven plates, three positive and four negative. The positive plates are of a dark

chocolate colour, while the negative are of a slaty-grey. The dilute sulphuric acid in which they are immersed should be of a specific gravity of 1190, attained by adding 1 part of pure H_2SO_4 to 5 parts of water. The dilution should, when cold, be tested by a hydrometer supplied for the purpose, and should be adjusted, if necessary, by addition of more H_2SO_4 or water according as the indicated density is below or above the desired standard.

The box encasing the cells, and its divisions, are usually lined with lead, and little strips or buttons of wood or glass are placed between the plates, to prevent them coming in contact during transport. If adjoining plates were allowed to touch each other while the cell was charged, they would be rapidly destroyed by the strong discharge of electricity. Over each cell of a portable set is a vulcanite or wooden cover, with a blow-hole in the centre; which hole must be plugged when the cells are being moved, but left open when the cell is being charged. Each box has its terminals painted, the positive red, and the negative black.

The capacity of an accumulator depends mainly and directly upon the quantity of lead in its plates, and is expressed in ampère-hours. Thus, '60-ampère hours' signifies that an accumulator can discharge 1 ampère for sixty hours, 2 ampères for thirty hours, etc.

Charging.—In **charging** an accumulator, the wire from the **positive** pole of the source must be **connected** to the **positive** terminal—that painted **red**—and the negative wire to the negative terminal—painted black.

It is of prime importance that no mistake be made in this connecting; for, if wrongly done, the accumulator will rapidly discharge, and may be totally destroyed.

A ready method of **judging the relative polarities** of the two wires leading from any source of supply is to lay them, about ½ inch apart, on a piece of moistened litmus-paper. At the positive pole is produced a red colour (acid), and at the negative pole a blue colour (alkaline).

The **rate of charging** may be indicated while in process by an ammeter in the circuit, but usually the means of charging is arranged for a certain rate, which is thus fixed.

The number of ampères permissible varies somewhat for different types of accumulator, but should always be in relation to the capacity of the cells. The maker usually marks on each set as sent out the proper maximum rate of charge and discharge, and these should never be exceeded, or the life of the accumulator will be considerably shortened. As a general rule, the charging current, expressed in ampères, ought not to exceed one-fifth, and the discharging current one-fourth, of the number expressing the capacity in ampère hours; thus, a 20-ampère-hour accumulator should not be charged with a current of more than 4 ampères, nor discharge more than 5 ampères.

Before commencing to charge, see that the plates are well covered by the acid; and, if the cells be covered or sealed for transport, see that the blow-hole is left open during the process of charging.

With a knowledge of the rate and duration of discharge of the accumulator since last recharged, one may calculate the time required, with a known rate of charging, to restore the total ampère hours of its capacity. But little, if any, harm can be done by overcharging, and full time should always be allowed for completion of the process. A ready method of telling when a cell is fully charged is to listen for the hissing effervescing sound produced by escape of the free gases. The intensity of this will depend, of course, on the strength of the charging current, but a little experience soon detects the indication. The acid, at the same time, turns milky in appearance.

Frequent recharging tends to preserve the efficiency of accumulators, and they never work better than when used and recharged daily. Even when not in use, they should be occasionally recharged—at least once in every three weeks—to keep them in good order. If one goes off for a holiday, they should be fully charged before being left.

If left at rest in a charged condition for any length of time, accumulators tend to deteriorate (as explained later); but they do so much more rapidly if left standing discharged.

They should never be fully discharged in working, the safe limit being indicated by a fall in the voltage of the derived

current. Each cell, as mentioned, gives a little over 2 volts when freshly charged, and the bulk of its charge (about 75 per cent.) is given off at that pressure. When the **E.M.F.** derived from an accumulator **falls** below 2 volts from each cell connected in series, it is imperative that it be **recharged at once.**

If, after recharging, an accumulator does **not register its normal voltage,** test each cell separately with a pocket galvanometer or a 2-volt lamp, so as to discover which cell or cells are at fault.

Short of serious damage, the failure of a cell to register its full voltage is frequently due to a fall in the level of the acid, caused by leakage or evaporation. (The possibility of leakage points to the necessity of having accumulators placed on leaden trays if they be kept indoors.)

In testing for a fault, do not, as is sometimes foolishly done, spark or flash each cell by connecting its opposite plates by a piece of wire, since such short-circuiting injures the plates.

The chance of such short-circuiting by accidental means must be prevented, a possible danger of this kind in transit having been already mentioned. Thus, in connecting up the induction-coil, fasten the ends of the connecting-wires to the coil before fastening the other ends to the terminals of the accumulator, thereby avoiding the chance of live ends coming into contact. Similarly, it is well to see that the accumulator boxes are not used as a shelf for depositing odd pieces of wire or metal, which may readily bridge the terminals and cause serious damage. In extreme cases, by such short-circuiting, plates may be completely crumbled up.

With careless working, it may soon be noted that an accumulator will **not absorb nor discharge the certified quantity** of electricity.

This is usually due to '**sulphating**'—that is, the formation of lead sulphate in a crystalline form, which may be seen as white patches on the positive plates. In a charged cell at rest there is always some leakage of current, and, as in usual discharge, lead sulphate is formed. This, as first deposited, is soft, and easily altered by recharging; but if that be long

postponed the deposit becomes crystalline, and is no longer altered by the current. This deposit reduces the available area of lead, and consequently decreases the capacity of the cell. Plates much affected become useless, and should be replaced by new ones.

The obvious **remedy** is **frequent recharging**. Where insoluble patches have already formed, they should be scraped off with a piece of glass or other non-conductor.

Some try to prevent sulphating by adding 1 ounce of caustic soda to 5 gallons of the electrolyte, but careful working should obviate trouble from this source.

Treated properly, a set of accumulators should do good service for many years, but the various points mentioned must be constantly attended to.

Accumulators may be charged by—

1. **Primary batteries.**
2. **Dynamo.**
3. **Public supply main.**

Each of those sources of supply is discussed elsewhere in this chapter, and we need only note here their suitability and method of use for the present purpose. The foregoing notes on charging are applicable to all.

1. **Primary batteries** need hardly be mentioned, since no serious worker would suggest their use for other than toy installations, and even there the batteries might better be connected direct to the coil.

2. **Charging by dynamo** is the usual method adopted to charge accumulators where no main supply is available; and, even where the latter source is available, unless it may be utilized without special transport of the accumulators, we recommend the former.

For a self-contained portable set we have already recommended the combination of dynamo and accumulators, whereby regular X-ray work may be done with only an occasional run of the dynamo. The driving power for the dynamo must be decided according to the special circumstances of each case. The various methods possible are discussed on p. 45.

The dynamo should be shunt-wound, and should supply

current of a higher voltage (4 or 5 volts more) than the total E.M.F. of the accumulator's strongest discharge.

The charging switchboard should carry a voltmeter and ammeter, and the current should not be switched on to the accumulator till the voltmeter registers the proper voltage.

Towards the end of charging the voltmeter will be observed to register much higher, with a corresponding drop in the register of the ammeter.

It is advisable to have an automatic switch inserted in the circuit between dynamo and accumulator, by which, if the dynamo should for any reason stop unexpectedly, the circuit would be at once broken. Otherwise, in such an event, the accumulator would rapidly discharge back through the dynamo, to the probable damage of both.

3. **Charging from Public Supply Mains.**—Where readily available, no one would seek other source than this for charging accumulators, but the current must be suitably regulated or modified before turning it on to the cells. Connection direct to the mains of a supply at any usual voltage would destroy the cells.

The methods of modification necessarily differ according as the supply is continuous or intermittent in character.

(*a*) **Continuous Current.**—Where installed, continuous current from the main should be used for direct supply to the X-ray installation, as described earlier, but for bedside work demanding portable apparatus accumulators will further be necessary.

For charging those a continuous current from the main is most convenient, some simple arrangement to regulate the rate of charge being all the intervention necessary. Such arrangement acts by way of resistance, allowing only the proper amount of current to pass from the main along the accumulator circuit.

Incandescent lamps suitably combined in parallel are commonly used for this purpose, their capacity being known and their action easily observed. Thus, at 100 volts one 16 candle-power lamp takes $\frac{1}{2}$ ampère—in other words, lets $\frac{1}{2}$ ampère pass on to charge the accumulator. One 32 candle-power lamp will take 1 ampère, as also will two 16 candle-power

lamps in parallel; so that, by arranging the power and number of lamps placed in parallel, an accumulator may be charged at any desired rate.

Fig. 19 shews diagrammatically an arrangement with four lamps in parallel, the positive terminal of the accumulator being connected direct to the positive pole of the supply, while the negative terminal has an ammeter and the lamp-

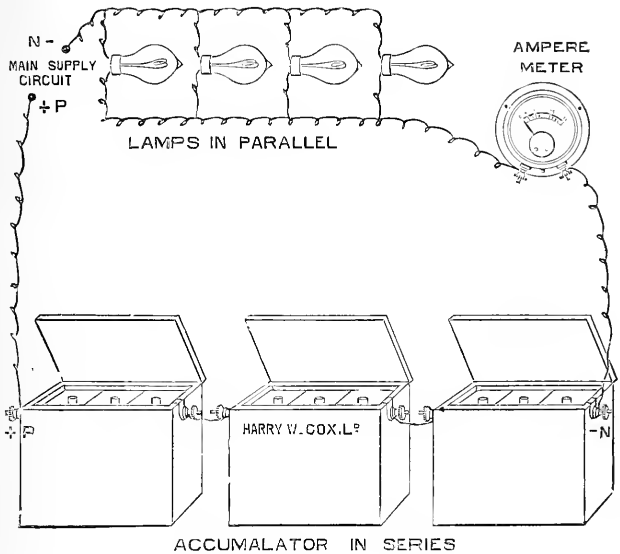


Fig. 19.

resistance interposed in its connection with the negative pole of the main.

Any wire of a pair connecting a lamp with the main circuit may be tapped for charging an accumulator by cutting it at some point, and connecting the severed ends to the proper respective terminals. But a more convenient method is to make or obtain some permanent arrangement of lamps, as shewn in Fig. 20. This may be connected with the main by a plug when required, and from its terminals connections passed to the accumulator. With lamps in circuit, the correctness of the connecting, as regards polarity, may be judged from

the brightness of their incandescence. When connection is correct, the lamp or lamps will burn dimly, since the residual current of the cells will be opposed to that of the main. If the connections be reversed, the lamp will burn very brightly,

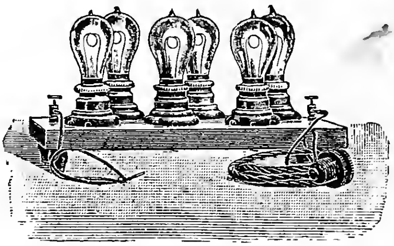


FIG. 20.

since the accumulator current will then reinforce that of the main.

But the method by use of litmus-paper, previously described, may prove more definite. Once determined, the

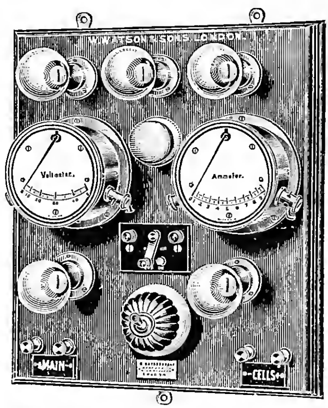


FIG. 21.

polarity of the arrangement employed should be marked for future guidance.

Where a plug is employed, it should be of a concentric type, thus making always the same connection with the main.

The ordinary bayonet-catch type may be inserted in either of two positions, and the polarity of the wires from it will differ according to the position. Hence, with such, the position must be indicated by corresponding marks on the plug and socket, or the polarity of the wires must be tested before each time of using.

Fig. 21 shews a permanent wall-board that would involve a minimum of trouble when once installed. The voltage of supply is there registered, as well as rate of charging, and there is also inserted an automatic cut-out.

(*b*) **Alternating current** cannot be used directly for charging accumulators, but some device must be interposed

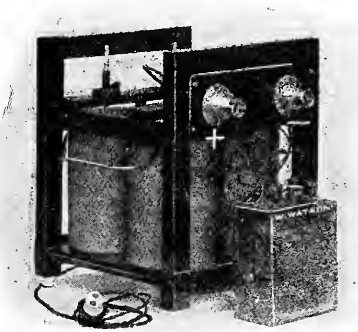


FIG. 22.

to render the current unidirectional. Many devices have been suggested and employed thus to 'rectify' the current. Those are mentioned, and some described, earlier in this chapter (p. 27); but, for the purpose of charging accumulators, we need only describe the device known, and already referred to, as Nodon's valve, aluminium cell, or electrolytic rectifier. In Fig. 17, on p. 30, is illustrated a set of those cells as made for sale, and on the preceding page will be found a brief explanation of the action of the device.

Fig. 22 shows a more simple arrangement of cells connected to an accumulator.

But efficient cells may be made from simple material by any one for his own use. Thus, a cell may be made from a

large jam-jar containing a strong solution of neutral ammonium phosphate, and arranged as shewn roughly in accompanying sketch (Fig. 23).

Into the jar dips an electrode of aluminium of about the thickness of a pencil, and a second electrode of thin iron—such as hoop-iron—from 2 to 3 inches broad, each electrode being about 9 inches long. Each electrode is shown suspended in the solution by being passed through a bar of wood or other suitable insulating material which rests on the top of

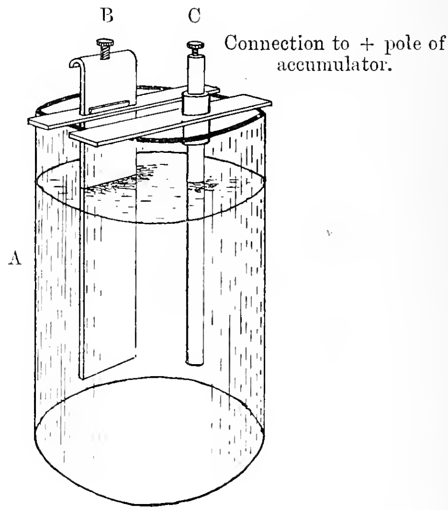


Fig. 23.—Simple Electrolytic Rectifier for Alternating Current. A, Glass jar containing neutral ammonium phosphate; B, electrode of hoop-iron; C, pencil electrode of aluminium.

the jar, the aluminium being made firm by passing through a cork and the iron being wedged in. At the top of each is a screw electrode for connecting wires.

We may repeat that the action of such a cell depends upon a property of aluminium (also magnesium), whereby as kathode it allows current to pass freely, but as anode it offers great resistance. Iron is a convenient material for the other electrode, since it is not acted upon by the electrolyte.

The solution should be a saturated one, and it is preferable to use distilled water in preparing it, as chlorides seem to

hamper the action. By escape of ammonia the liquid becomes acid, and crystals tend to form. To obviate this, a little weak ammonia solution should be added occasionally. Periodically—each three or four months—the cells should be taken apart, the solution filtered and replenished, and any deposit on the plates or cell scraped off.

In action a certain amount of heat is generated in the cell, and if the temperature rise above 70° F., the efficiency falls. Thus the size of cell and quantity of electrolyte should be proportionate to the quantity of current passed through the cell; but the aluminium should be kept small in area. The cell should be placed between the lamp-resistance and the accumulator, with the aluminium electrode connected to the positive terminal of the latter.

A cell of about the dimensions described should act well with a current of 100 volts passed through a 32 candle-power lamp. Where current supplied is at a higher voltage, it will be profitable for regular use to pass it first through a transformer, whereby pressure will be reduced to 50 volts, and the ampèrage correspondingly increased; otherwise two cells in series may be employed to deal with the heavier voltage, though this is not so efficient.

Using only one such cell or two in series, it will be readily seen that half of the current will really be lost, since only one of its two periods or phases is transmitted to the accumulator. Also the back electro-motive force of the phase suppressed will rapidly heat the electrolyte and wear down the aluminium. Fig. 24, however, shews a plan of connecting up two cells whereby both phases of the current may be utilised, the accumulators receiving alternately the single periods or phases as allowed to pass by the cells. By following out the connections as shewn in the sketch, and noted under it, the action will be more clearly understood than by verbal description. Besides utilising almost the full energy of the current supplied, this arrangement lessens the heating of the electrolyte and the wear of the aluminium electrode, since one or other path is always open to the current, and the back electro-motive force in each cell is thus minimised. Each accumulator will be charged at half the rate correspond-

ing to the power of the lamp used. Thus, with a 32 candle-power lamp in series, with a 100-volt supply, each will receive about ½ ampère.

The above arrangement assumes that two or more accumulators will be charged at one time. For a single accumulator an arrangement of four cells is possible, arranged after the manner of a Wheatstone bridge; but for X-ray work more than one accumulator will practically always be in use.

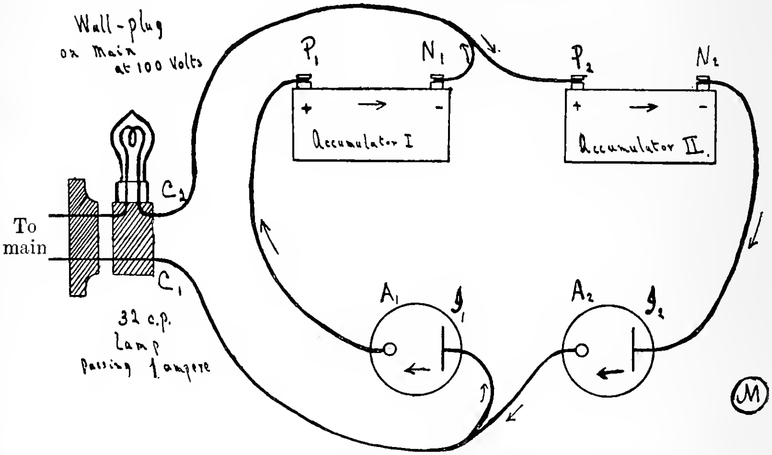


FIG. 24.—ARRANGEMENT OF TWO ELECTROLYTIC RECTIFIERS TO USE BOTH PHASES OF ALTERNATING CURRENT.

One phase passes from C_1 by I_1 and A_1 to P_1, charges Accumulator I, and returns from N_1 to C_2; other phase passes from C_2 to P_2, charges Accumulator II, and returns by I_2 and A_2 to C_1.

III. Primary Batteries.

Primary batteries are of little, if any, practical use in X-ray work. The requisite current can indeed be obtained if a sufficient number of cells be suitably connected; and for such a purpose bichromate cells, or Bunsen's cells (each with an E.M.F. of about 2 volts), will probably be found most suitable. But it is hard to conceive of any set of circumstances in which it would not be much more convenient and efficient to employ some other source of supply.

IV. Dynamo Machine.

A **dynamo-electric machine** (briefly termed a dynamo), suitably driven, forms a valuable source of supply where such must be instituted in the absence of, or independent of, a general supply. Thus, on board a ship in which electric light is not installed, in hospitals in isolated or country districts, or specially adapted for field service, this type of supply has much in its favour.

The dynamo may be constructed to supply current suitable for the special purpose in view, and some amount of regulation will be possible for variation of speed, though for each

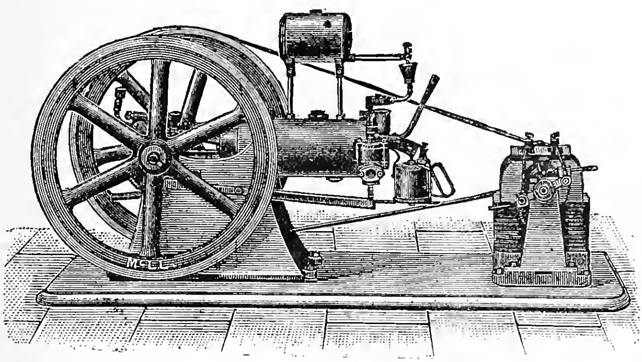


Fig. 25.

machine there is a certain rate of speed at which the greatest efficiency of action is obtained.

The choice of a special form of driving-power will depend mainly on the circumstances of the installation.

Where there is a pre-existent supply of power, with sufficient margin, the dynamo should, if possible, be driven from that, either by a direct chain or belt drive, or by way of an intervening countershaft, whereby variation of speed may be obtained, if that be desired.

Where no power-supply exists, and the installation is to be stationary, a small gas or oil engine will usually be the preferable power for driving. Special circumstances may make a steam-engine preferable. Where a sufficient water-

power is available and convenient, an economical drive may be obtained from a water-turbine. This plan is highly commendable, wherever possible.

Where portability is a main consideration—as for field-service—various special adaptations may be employed. The dynamo itself should be of as light a pattern as may be compatible with efficiency, and may be constructed of detachable sections if difficulties of transport make that advisable. Driving-power may be derived from one of the traction-engines or motors now so generally employed in transport; or a special motor might readily be designed to transport the

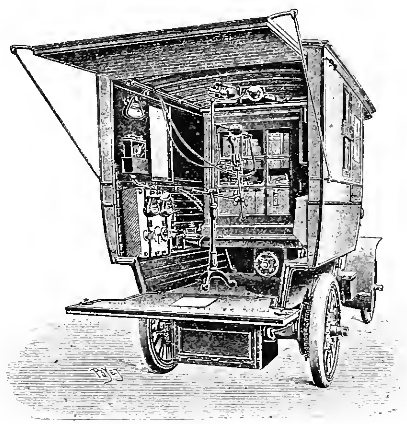


Fig. 26.

dynamo and other X-ray outfit, and also serve as driving-power for the dynamo when so required. An automobile of this description, recently designed for field service in the French army, is illustrated in Fig. 26.

A still more portable outfit may be designed for driving by horse-power, as shewn in Figs. 27A and 27B. Where men are readily available—as in the services—a pedal gear may be arranged, similar to the driving gear of a bicycle. In emergency, a serviceable drive may be obtained by supporting an actual bicycle frame, and connecting the dynamo by belt to the back wheel.

V. Static Machine.

Static or influence machines form a possible, and for some purposes an excellent, source of supply where portability

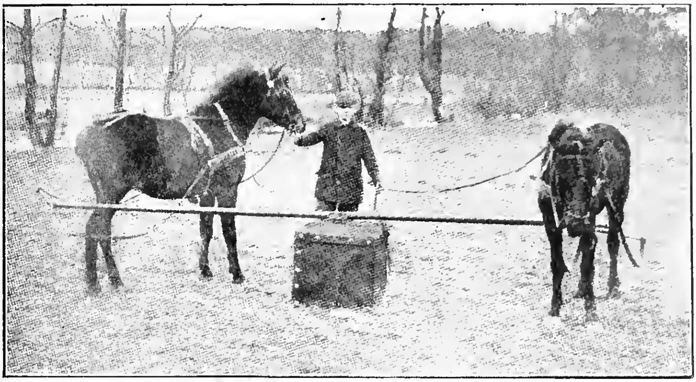


Fig. 27a.—Horse-Gear Dynamo in Use.

is of no account. They have the great advantage of being self-contained; for, with the power required to drive it, one of these machines can supply current direct to the X-ray tube

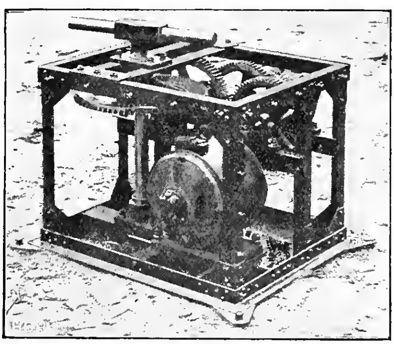


Fig. 27b.—Dynamo and Horse-Gear, with Cover removed.

without addition or intervention of other apparatus. For the same reason, they are as a rule simple to use, though at times somewhat uncertain in action.

For screen-work they produce brilliant, steady illumination of a suitable tube, and are for this purpose excellent. For photography, a tube so excited requires a long exposure, but very good radiograms are produced. If such work be attempted, a tube specially made had better be employed.

Absence of reverse currents, and the improbability of overheating, prolong the life of the tubes considerably.

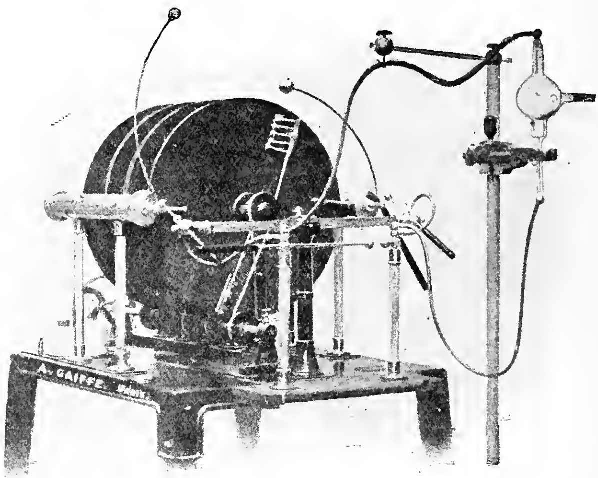


Fig. 28.

As mentioned at the beginning of this chapter, the static machine is a favourite source in other countries, and in this country there is a probability of an improved form coming into favour rapidly when it is introduced, as we expect it to be shortly. At the present stage, however, it would not be profitable to do more here than refer readers to works on static electricity, where those machines are specially described and considered.

CHAPTER III

INTERMEDIATE APPARATUS

Interrupters or Breaks—Induction Coils—Valve Tubes, etc.

[Appended to this chapter will be found an explanation of the action of an induction-coil with vibrating break, and instructions for use, which we have by request dealt with in some detail.]

For excitation of an X-ray tube, we have seen to be required an electric current of very high potential or electro-motive force.

No source other than a static machine directly supplies current of sufficiently high potential; therefore, unless in the case of such machine, a transformer must be interposed between the source and the X-ray tube. For this purpose an induction-coil is ordinarily used. But the current supplied to an induction-coil must be a regularly interrupted current, and to produce such interruption an auxiliary piece of apparatus is usually employed, known as the interrupter or break.

These two pieces of apparatus—coil and interrupter—should always be considered jointly, and designed mutually to suit each other. Different breaks produce very different rates of interruption, and no single coil can be expected to work efficiently with widely varying rate of interruption. Thus, a coil wound to suit a low rate cannot be 'saturated' by each fractional current sent to it by a break giving a much higher rate of interruption; and, conversely, a coil wound to suit a high rate of interruption cannot respond efficiently to the longer periods of excitation allowed by a more slowly acting break. The duration of each contact, or 'make,' during which current is allowed to pass to the coil is also determined by the

interrupter, and may be varied according to the result desired. For this also the coil should be adapted. An important point in the action of an interrupter may be here noted—namely, the **break** of the current must be as **sharp and sudden** as it can possibly be made. Many workers have made the mistake of applying to the same coil interrupters of varying construction and rate of interruption, and have been prone to judge the interrupter according to the result obtained, possibly ascribing failure to the construction of an interrupter rather than to the true reason of inco-ordination between it and the coil employed.

A coil may be badly damaged also by using with it a break different from that with which it was designed to work. Thus, by substituting a break which passed a much heavier current than the break originally used, we had a coil seriously injured, and we know of at least one London hospital where several coils were rendered useless by such a change injudiciously made.

The choice of coil and interrupter depends upon the demand likely to be made on them—that is, upon the nature of the work to be done.

For **radioscopy** or screen examination we wish a steady fluorescence; hence rapidity of interruption will be the criterion. For **radiography** the same high rate is not essential, but will lessen the requisite length of exposure. Since those two classes of work are usually combined, we may say that for such work a fairly high rate of interruption is essential, up to 3,000 per minute.

In **radio-therapy**, on the other hand, there is no especial call for rapid interruption, and a rate of 1,000 per minute will be more than sufficient for such work. The duration of exposure will here frequently be much in excess of those employed in the other classes of work, varying from five to twenty-five minutes, so that unless the apparatus be designed to stand such prolonged runs, it may be unable to withstand the strain.

Where one or other class of work distinctly preponderates, the installation should be designed to suit that work; where neither preponderates, a compromise must be struck, unless

the installation may be duplicated. Some recent coils are made with arrangements for adjustment to suit varying conditions, and with an interrupter of wide margin of rate may be made to suit the work in hand, but never so efficiently as a coil designed specially for specified conditions.

With a knowledge, then, of the nature of the work to be done, the radiologist may settle what rate of interruption will be most suitable, and he will have a coil built to suit; but first he will settle on the interrupter likely to fulfil the conditions.

Interrupters or breaks are in type many and various. They may be classified as—

1. Vibrating or platinum.
2. Motor mercury, including—
   (*a*) Dipper type;
   (*b*) Turbine or jet type.
3. Electrolytic.

1. The familiar **vibrating or Nieve's hammer,** or one of its more recent modifications, such as the 'Vril' contact-breaker, is still used occasionally on a coil as interrupter. Such arrangement is serviceable where portability is of prime importance. The rate of interruption is with such, however, greatly limited, about 1,000 per minute being a maximum; nor can currents of other than moderate strength be safely used—say, about 20 volts maximum—as their action with stronger currents is not reliable enough to safeguard the coil. The slow rate of interruption makes their use very unsatisfactory for screen-work, since it produces an unsteady illumination. The smaller currents alone permissible necessitate long exposures for photographic work. Despite these disadvantages, we have obtained quite satisfactory radiographs with such an arrangement, where circumstances required transport of apparatus to the bedside. With this class of break used for radiographic exposures a high rate of interruption should not be aimed at, since with that there is apt to be insufficient current passed into the coil, and 'saturation' is not attained (see further, p. 73). Fig. 29 will recall

the arrangement of this form of interrupter attached to the induction-coil.

Regulation of the various tension screws should be attended to, and the platinum contacts kept always in good order, to insure full efficiency in working.

The vibrating or hammer break is still largely employed in both army and navy services; but for attainment of best results, and especially for employing the heavier currents now found so advantageous, it seems advisable that these breaks should be replaced by some more recent form.

For the benefit of workers whose practice may be confined to, or chiefly concerned with, such form of apparatus, we have, by request, appended to this chapter some notes on the connections and working of a coil with vibrating break.

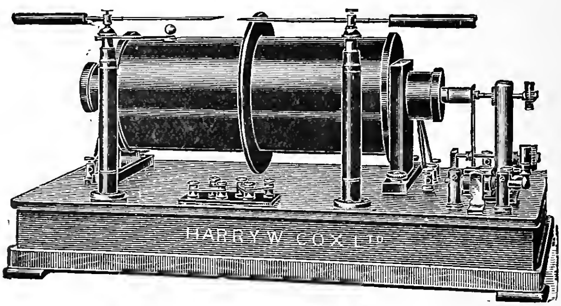


FIG. 29.

2. (*a*) The **dipper** break makes and breaks contact by means of a metallic rod alternately dipping into, and being withdrawn from, a reservoir of mercury, from which a connection passes to complete the circuit. The mercury is covered by a layer of liquid, such as alcohol or paraffin, so as more effectually to quench the sparks produced in action of the break.

There are two main designs of this type of break, one with a **perpendicular** dipper and the other **rotary**, each being driven by a small motor on a circuit independent of the circuit of supply to the coil.

The **perpendicular** dipper is worked by a crank motion attached directly to the shaft of the motor. It allows of simple

and exact regulation of the amount of dip and consequent duration of contact, as well as of the rate of speed. This is a simple and straightforward mechanism, and does not readily get out of order. It is also easily cleaned, so that an instrument-maker need seldom, if ever, be called in to assist in its continued working. A high rate of speed cannot be attained —about 1,000 to 1,500, and the break is somewhat noisy in action, but for combined work it acts on the whole very well.

The **rotary** design of dipper break, usually associated with the name of Mackenzie Davidson, has an inclined axle, on which the dipping blade or blades are fixed radially. Those

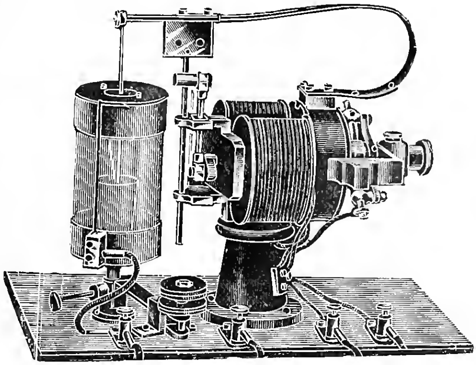


Fig. 30.

radial blades make and break contact with the mercury while the axle revolves. With this break a higher rate of speed can be attained than with the perpendicular dipper, but the intervention of a belt drive, as in the usual form, is a disadvantage; while the mechanism is less simple, and may require skilled assistance more frequently to keep right. More recent forms have the motor set on an inclined base, and the vanes attached to a direct prolongation of its shaft, as shown in Fig. 31.

Either of these dipper breaks serve very well for moderate currents and for medium rates of interruption.

When at rest, the plunger or vane of a dipper break may be arrested at the end of its dip—that is, immersed in the mercury—and if the current were suddenly switched on, it would

pass direct to the primary of the coil, and possibly do much damage. Hence, it is important to see always that the motor is in action before the supply current is switched on. This is secured in our installation, as described later, by a special form of switch.

The churning action of the break gradually causes some degree of emulsification of the mercury and the covering fluid (or dielectric); thus these materials require periodical renewal. More or less of the mercury can always be recovered, and, with this in view, alcohol will be found to be the preferable material for a dielectric, as making the process of

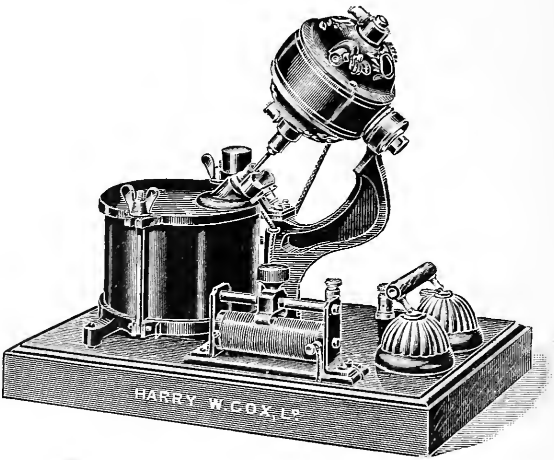


Fig. 31.

recovery much less unpleasant. Methylated spirit is commonly used, but it is better to use rectified spirit; for, though initially more expensive, it requires changing much less frequently, and, further, has less corrosive action on the metal parts. The level of the alcoholic liquid must be kept well above the highest point of travel of the dipper, or otherwise the liquid may ignite, causing an alarming, if not dangerous, explosion.

To clean, the emulsified liquids should be allowed to settle, the clearer spirit settling out on top decanted off, and the mercury heated gently in a retort with condenser attached,

whereby the remaining spirit is vaporised and the mercury recovered for further use.

Another method of cleaning the emulsion is to wash it in an open jar placed under a tap, and let the washings settle for a week.

To avoid this inconvenience, many recent types of break are constructed so as to employ gas as a dielectric.

(*b*) The **turbine or jet** type of **break** has an action indicated somewhat by its name. When such a break is set in motion, a jet of mercury is by centrifugal action propelled

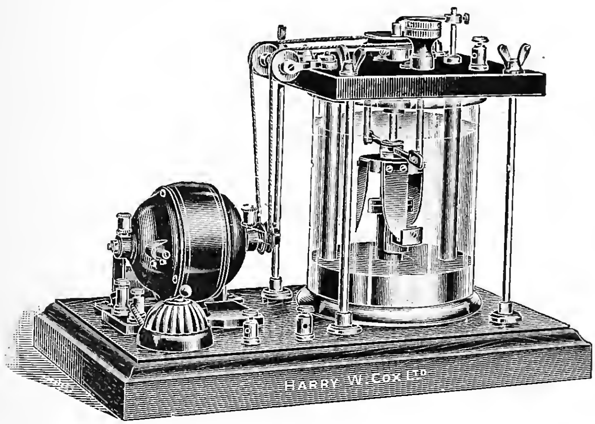


Fig. 32.

radially from a central stem, and makes contact with a rapid succession of peripheral sectors of metal, having between them intervals of insulating material.

The succession of makes and breaks is obtained by a rotary motion of either the central stem carrying the radial jet with it, or of the peripheral sectors while the jet is in a fixed direction. In the earlier and more common designs, speed and rate of interruption can be directly regulated by altering the current sent to the driving motor. The metal sectors can be varied in number to secure a similar regulation, and these sectors are further made of a triangular shape, so that vertical adjustment may vary the width of metal exposed to the jet, and consequently the duration of contact. The surface

of the mercury is in this form of break, as in the dipper type, covered by some insulating and spark-extinguishing liquid, paraffin being here usually employed.

With this type of break at rest, there is no danger of the continuous current being accidentally passed direct to the coil, since the jet by which the contact is made is not formed until some rate of speed is got up.

A higher rate of interruption may be obtained with such a break than with a dipper; but for lower rates of interruption

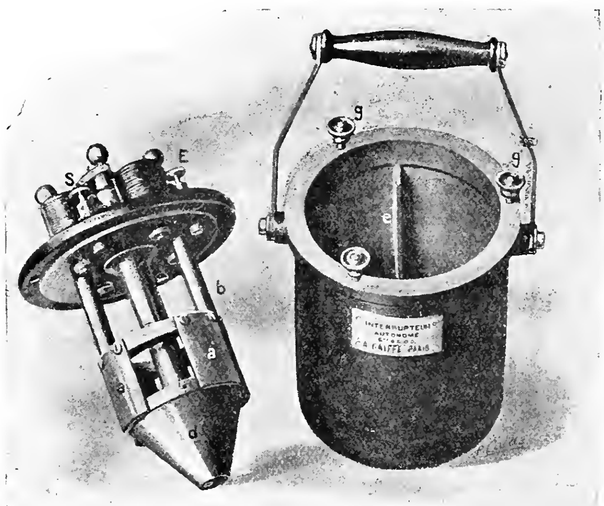


Fig. 33.

those breaks are not good. For a time the action at a suitable rate is very satisfactory; but the break is somewhat easily put out of order, and requires frequent cleaning, which is a difficult and dirty process. More recent forms are simpler in construction and more easy to clean when clogged.

The earlier forms (as in Fig. 32) are driven by belt-connection from the motor, and the slipping of this may cause much inconvenience. More recent jet breaks are driven by some electro-magnetic arrangement directly connected to the rotating parts.

Thus, in Gaiffe's form (as shewn in Fig. 33), four electro-

magnets are situated on the cover of the instrument, and through the coils of these the current passes before entering the interrupting mechanism on its way to the primary of the induction-coil. This is a doubtful advantage, since the rate of interruption cannot be varied independent of the strength of current supplied to the coil, or *vice versa ;* whereas that is a latitude desirable under certain conditions. With a heavy load the action is somewhat noisy ; but this is on the whole a reliable instrument, and has the further advantage of being less than half the price of the older forms.

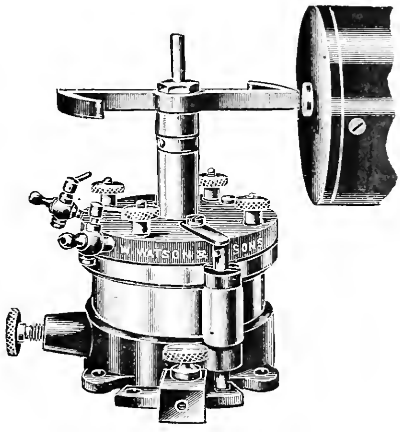


Fig. 34.

In a recent modification called ‘ The Intensive Break ’ very heavy currents, quoted as 25 ampères at 110 volts, may be passed through such a break if desirable. This is a decided advantage, though the price is somewhat higher than for the ordinary form.

A recent **London make** (illustrated in Fig. 34) is driven by a star-shaped magnet of soft iron, which is mounted on the upper end of the jet shaft. This is rotated by influence of the successive magnetisations and demagnetisations of the core of the induction-coil, opposite the end of which the instrument is set. In this break the jet-producing portion is enclosed in an air-tight metal reservoir filled with coal-gas or

hydrogen, which acts as a dielectric to cover the points of contact instead of the usual liquid. This avoids the formation of sludge, and consequent inconvenience of frequent cleaning. The speed may be regulated somewhat by altering the position of the interrupter relative to the coil, thus requiring no special rheostat; but this regulation of speed is not thoroughly satisfactory. The break is quiet in action, even with heavy currents, is of comparatively moderate price, and we reckon it one of the best turbine breaks on the market.

To avoid the starting by hand, which necessity may be somewhat inconvenient, the makers also supply a small independent coil, by which the break may be driven and continue in rotation whether the larger coil be in or out of circuit.

3. **Electrolytic breaks**, commonly known as Wehnelt's breaks, from the name of their originator, are now extensively used as specially suitable for the heavier currents desirable for rapid radiographic work. With these breaks a much more rapid rate of interruption can be obtained, and they are capable of transmitting currents heavier than any X-ray tube at present made can stand for more than a few seconds. They may be used with alternating current (as mentioned earlier) or with continuous current, but work more efficiently with the latter.

As the name indicates, these breaks depend upon the electrolytic action of a current passing between electrodes immersed in a liquid. If one electrode be of very small area, the bubbles of gas formed tend to collect on it, and thus interrupt the continuous passage of the current; then almost instantaneously these are dissipated, and the current is again free to pass. A regular succession of accumulation and dissipation of bubbles renders in this manner the current passed through the cell intermittent in character, and the periodicity so obtained is much more rapid than with any form of mechanical interrupter in use. In practice, the electrode of small area is the anode, and is composed of platinum, while the kathode consists of a lead plate of large area.

Dilute sulphuric acid (1 in 10) is commonly used, though

other fluids have been suggested as more suitable for certain purposes. A cell containing such fluid, and having immersed in it two electrodes as described, represents the total essentials of the break, though many elaborations of adjustment have been introduced.

An arrangement, which constitutes probably the utmost extent of elaboration consistent with efficiency and economy in regular work, might consist of a large-sized glass cell, having immersed in the fluid a cylinder of porcelain, from

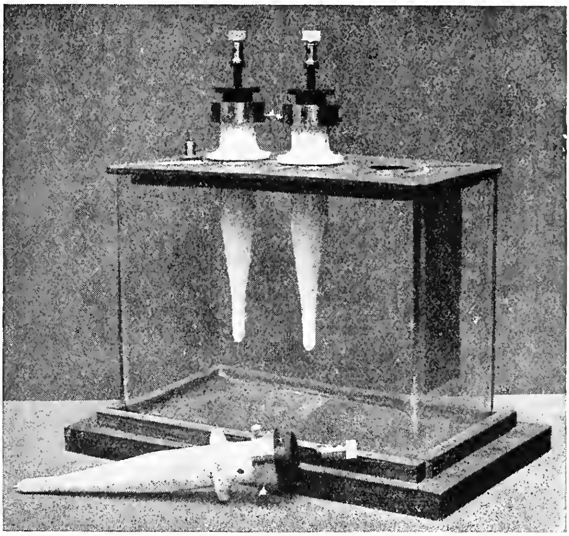


FIG. 35.—TRIPLE WEHNELT INTERRUPTER, WITH LEAD COVER.

the bottom end of which a platinum wire projects to an extent variable by a screw at its upper end, and having, further, a kathode in the form of a sheet of lead of suitable size.

The triple type illustrated in Fig. 35 is now generally used, as it permits a much wider range of adjustment and regulation (in combination with the primary winding of the induction coil) than the single type just described.

As further illustrating the simplicity in essentials of this form of break, we represent in Fig. 36, and describe, one which may be made for himself by anyone who has even but

slight manual dexterity, and that for a few pence, or, at most, a few shillings.

An ordinary earthenware or glass jar may be used as a containing-cell—the larger the better. Through the closed end of a test-tube seal a short length of platinum wire, and into the tube pour mercury to a height of 1 inch or more. Through a wooden cover to the cell, or in some other suitable manner, as in Fig. 36, suspend the test-tube immersed deeply in the fluid, and to make connection, dip a wire from the

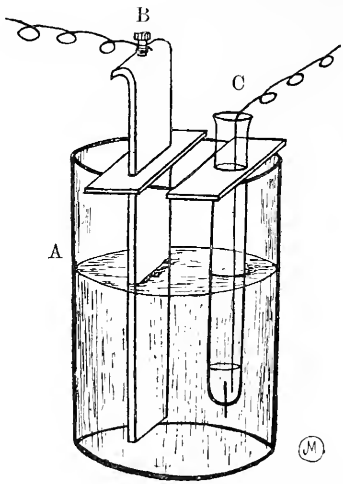


FIG. 36.—HOME-MADE WEHNELT INTERRUPTER.
A, Glass jar containing dilute sulphuric acid (1 in 10); B, sheet-lead with terminal; C, test-tube with platinum point and containing mercury.

positive pole of the source of supply into the mercury. Then hang over the edge of the cell a piece of sheet-lead reaching to near the bottom of the fluid, and having a screw at its upper end to bind a connecting-wire from the negative pole of the source, and your electrolytic break is complete.

A break so constructed we know from experience to work very satisfactorily, and it can be renewed many times for the cost of one of the more elaborate breaks put on the market, which will give little, if any, better results.

With electrolytic breaks the frequency of interruption will

vary according to the pressure of current supplied, higher voltages producing more rapid interruption. By exposing a larger area of the platinum anode to the fluid the rate of interruption is reduced, and by exposing less the rate is accelerated. The increased area of exposure allows a higher ampèrage to pass. With the electrodes suspended from separate strips of wood, glass, or other insulating material, as shown in Fig. 36, some regulation of the action may be secured by moving the two electrodes to various distances apart.

For working with this form of break, an induction-coil with short primary winding should be employed, since the self-induction of longer primaries prevents the full effect of the break's special efficiency reaching the X-ray tube.

The condenser of the coil should in all cases with these breaks be put out of circuit.

In action, and especially with heavy currents of high pressure, electrolytic breaks are very noisy; so the whole cell and attachments should be cased in felt, to deaden the sound, and the break should be kept in a separate closed room where possible.

With heavy work the electrolyte becomes very soon heated, and operation of the break is thereby embarrassed, and later stopped. A cell of large capacity should therefore be employed to delay the heating effect, and that may be set into a larger vessel containing cold water if continuous heavy work is expected.

The cells require no cleaning, which is a great convenience.

For use with currents of small quantity and low potential, as from batteries, these breaks are unsuitable.

They require for efficient working a current of about 40 volts or more, will not work under 30, and work best between 60 and 80 volts. Unless for specially strong currents indeed, such a break is not advisable, since its action is not reliable enough to commend it for ordinary purposes for which other breaks may serve.

It is important that an electrolytic interrupter should be connected correctly, the **platinum to the positive pole** of the source. If connected otherwise, the platinum will gradually

dissolve, or possibly fuse if thin, and the coil will not work well. If the direction of current be correct, the sparks in the interrupter have a red colour; if wrong, they have a blue colour. Litmus-paper can, of course, give us the necessary indication before connection is made, the positive pole making a red stain on the moist paper, as described in the section on the charging of accumulators.

On the Continent electrolytic interrupters are used commonly, but in conjunction with coils specially made to suit them. The chief check to their use here is the heavy mortality amongst tubes, most of which can stand the heavy current transmitted for a very brief period.

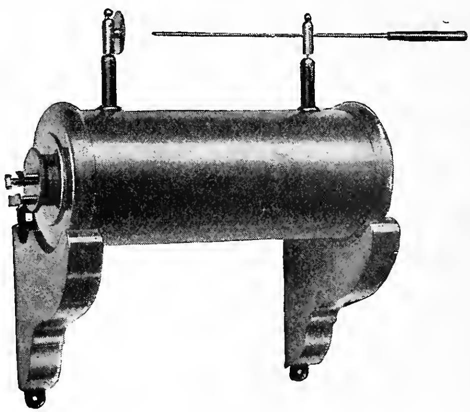


Fig. 37.

Induction-coils have been already referred to in the introduction to this chapter, and some of the conditions of their working discussed. We do not propose to enter into any detail of their theory or construction, since those will be found sufficiently described in any modern text-book on electricity. (A few notes on their practical working are appended to this chapter for the convenience of workers not familiar with them.) The coil forms, however, a most important part of an X-ray installation, and it is advisable that every operator should make himself thoroughly acquainted with its theory and practical working. For our present purpose it is sufficient to recall that its function, broadly speaking, is to raise or

convert the E.M.F. of the current supplied to a voltage suitable for the X-ray tube. The degree of this function may be appreciated when we note that to produce a 12-inch spark across the discharging points of a coil requires a potential of about 148,000 volts. This increase in voltage is obtained at a corresponding loss in ampèrage, and the product of the two factors—technically expressed as Watts—in the current derived from the coil should approach that in the current supplied, a slight loss being inevitable. No satisfactory method exists, however, whereby the output of a coil may be accurately measured.

The action of a coil is commonly expressed in terms of the length of spark which it is able to send across the terminals of its secondary when the primary is supplied with a suitable exciting current, but this expression is misleading.

Formerly, indeed, it was the custom to consider the spark-length as synonymous with the power of a coil to do good X-ray work, and a spark of from 16 to 20 inches was considered a desideratum for a good X-ray coil. But we now recognise that a coil with a maximum spark of 10 to 12 inches may be capable of satisfying all our requirements, and we pay more attention to the nature or 'thickness' of the spark emitted. Thus, in our hospital installation, the coil gives us the full spark-length with a current of 4 ampères, but we commonly use 6 to 8 ampères, and may pass as much as 12 ampères at an odd time. The additional current does not lengthen the spark, but increases its intensity or fullness. This coil, we may say, is designed to work nominally with interruptions at the rate of 600 per minute, this being considered a mean rate for usual work. There is, of course, a margin of reasonable efficiency above and below this rate. With 8 ampères passing, the break works on steadily with a regular 'dick-dick' bruit, but on approaching 12 ampères the sound becomes lower-pitched and laboured, denoting that the coil cannot absorb or utilise the surge of current supplied to it.

We have said that a great potential spark-length is not essential for a good coil for X-ray work; it is, indeed, undesirable. From a coil emitting very long sparks it is difficult

to obtain more than 1 milliampère of current, whereas with the shorter and coarser winding suitable for shorter sparks we may obtain a current of 10 to 15 milliampères. No tube presently made could stand that current for more than a few seconds, so that alteration of coils in that direction is for the present limited in its utility. Long sparks are correspondingly 'thin' and thready. What is now wanted for general use is a spark of moderate length, but 'fatter' quality—sometimes described as 'flame-like.'

Some recent coils have their primary windings made in separate sections, so that a greater or less length of wire may be put in circuit according to the strength of current supplied to the coil, a shorter length, as represented by a less number of sections, being employed for heavier currents.

The current sent from an induction-coil through an X-ray tube consists of a rapidly recurring series of brief currents induced in the secondary circuit in consonance with the interruptions of the current sent to the coil from the interrupter or break. This secondary current will depend initially upon the strength of the primary current employed; further, upon the rate of interruptions of that current; and, as regards the coil, mainly upon the relative lengths of the primary and secondary windings thereon. It may be recalled that this inductive effect is due to the interruptions of the primary current. The suddenness of those individual interruptions, as well as the duration of actual passage of current in the intervals, will affect the character of the secondary current induced. As already noted, the break in the current produced by the interrupter must be as sharp and sudden as it can possibly be made.

At each 'make' of the primary current a momentary current is induced in the secondary circuit in a direction opposite or 'inverse' to that in the primary, and at each 'break' there is induced a momentary 'direct' current of greater power. Those direct currents at break are alone desired in the discharge of the coil for X-ray purposes, the inverse currents, as mentioned earlier, being of damaging effect. The actual E.M.F.'s of the two induced currents are equal; but the current at 'make' is more slowly induced, and

this delay is increased by use of a condenser, while at 'break' the secondary current is induced much more sharply. Thus the currents at break may be said to be in quality more 'impetuous,' and manifest themselves as sparks; while those at make are more 'deliberate,' and fail to form sparks under ordinary circumstances. Where the potential of the primary current exceeds 50 volts, however, the effect of these 'make' or inverse currents becomes noticeable in the fluorescence of the X-ray tube. This effect is marked by a flickering, greenish fluorescence in the hemisphere of the tube ordinarily free from illumination.

A tube under such conditions is not reliable for photographic exposures, and rapidly suffers in quality in the manner described in the section on 'Changes during Operation' (p. 11).

To check off these inverse currents some arrangement is frequently interposed in the secondary circuit between the coil and the anode of the X-ray tube, and for the best photographic effect this should always be done. Such check is necessary with high voltage, with a rectified alternating current, or with a very rapid series of interruptions.

A **Villard's valve-tube**, or 'soupape,' is the usual piece of apparatus so employed. This consists, as shown in Fig. 38, of a vacuum-tube of moderate degree of exhaustion, having one end drawn out as a slender prolongation of the central space. Into the main space projects a terminal of thick aluminium wire in the form of a corkscrew; and in the farthest part of the prolongation is the second terminal, formed by a slender rod of aluminium. So long as the larger corkscrew-shaped terminal acts as a kathode the tube conducts easily, but to currents in the opposite direction it offers a high resistance. If this tube be placed in proper relation to the X-ray tube, it will be readily seen how it will oppose the passage of the inverse currents described, whilst allowing easy passage to the direct currents desired for use. In series with an X-ray tube the correct setting may be remembered by noting that platinum alternates with aluminium. The platinum anode of the X-ray tube should of course be towards the positive pole of the induction-coil,

and the valve-tube is interposed on that side. Fig. 38 shews the arrangement diagrammatically, but in practice the valve-tube should be interposed, as in Fig. 40, between the coil and the sparking pillars, otherwise the alternative spark will measure the resistance of the valve-tube in addition to that of the X-ray tube, and thereby convey a false idea of the condition of the latter.

Readings on a milliampèremeter placed in the secondary circuit show that this action is more than theoretical, and

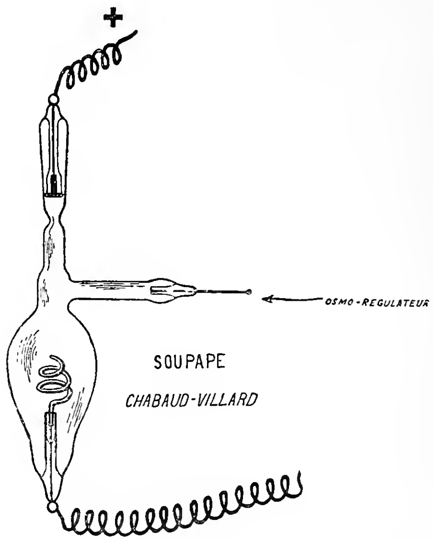


Fig. 38.

experience in working installations also testifies to the advantage of the device. A vacuum regulator should always be attached to the valve-tube, otherwise needless resistance may be opposed to the current.

An **adjustable spark-gap**, as illustrated in Fig. 39, may be interposed in the secondary circuit for the same purpose of cutting out inverse currents, and is so used commonly with static machines. For heavier currents, as from coils, this is a somewhat noisy working arrangement; but such an arrangement as is shewn in Fig. 39 allows much more easy regulation

to suit the resistance of different X-ray tubes than does a valve-tube.

By screwing the point home till it touches the plate the spark-gap may be abolished; by screwing back the point the resistance can be increased gradually, till the light in the tube indicates that the inverse current has ceased.

Where tubes of different hardness are used in succession, this ready means of regulation is of great value, and its effect on the appearance of a tube is often very striking.

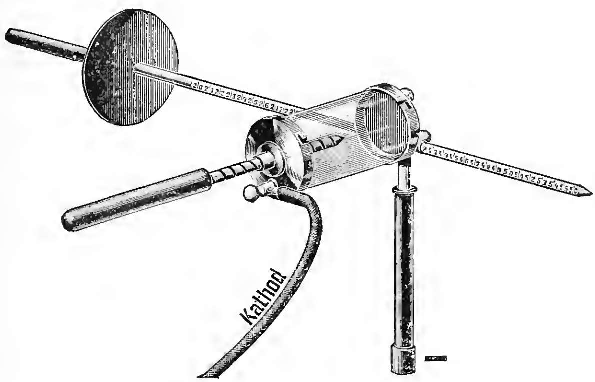


FIG. 39.

The use of the **spintermeter** and **milliampèremeter** in the secondary circuit of the coil has already been explained, and the annexed diagram (Fig. 40) shews their arrangement during operation.

Working of an Induction-Coil with Vibrating or Hammer Break.

Since the efficient working of an induction-coil depends in so large a degree upon an intelligent understanding of its principle and construction, we have on request decided to add here, as in the case of accumulators, some more theoretical and detailed instructions to workers.

We will not describe details of construction, since those vary somewhat, and are dealt with in a more or less lucid way

in most catalogues of electro-medical instruments, as well as in works on theoretical electricity.

The external appearance, doubtless familiar to all our readers, is recalled by Figs. 29, 37, and 45.

Fig. 41 shews diagrammatically the arrangement of essential parts.

Considering the primary current as entering at (A +), it may be traced up the metal pillar (G), across platinum points at

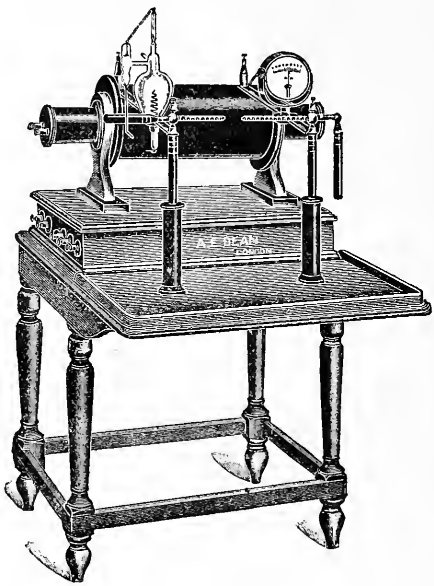


Fig. 40.

(H) to the hammer (J), down the spring (D), and thence to the primary winding of the coil (*bb*). By that it is led round the core (*aa*), then back to the other terminal (A −).

The core (*aa*), consisting of a bundle of wires or thin sheets of soft iron, becomes rapidly magnetised by influence of the current circulating round it.

By force of magnetic attraction it draws the hammer (J) to wards it, and thus separates the two platinum points at (H).

This separation interrupts the flow of the current, the core consequently loses its magnetism, and the ham mer (J) returns

by force of its spring (D) to its former position. Contact at (H) is thus restored, current passes as before in the primary, the core becomes again magnetised, and this cycle of events is repeated automatically as often as the succession of 'make' and 'break' at (H) will allow. The alternative path (*dd*) to the condenser (*ee*) will be dealt with later in reference to the suddenness of the break.

The secondary winding, which consists of many thousands of yards of very fine insulated copper wire, is not shewn in Fig. 41, but its position is within the bobbin (KK), and its endings are seen emerging at (FF), from which points connection is made to the X-ray tube.

Following the laws of induction, at each **make of the**

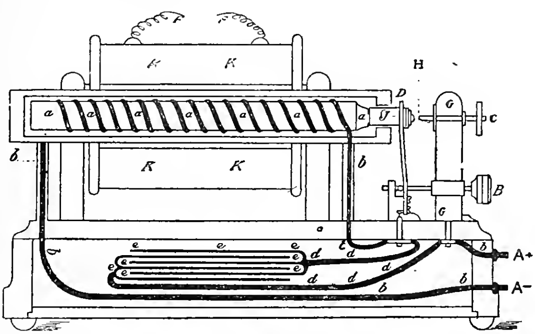


Fig. 41.

primary current a momentary current is set up or **induced in the secondary** circuit in a **direction opposite** to that in the primary; and at each **break** of the **primary** a momentary current is **induced in the secondary** in the **same direction** as the primary.

Thus, in the secondary circuit is set up a series of currents alternating in direction, their periodicity depending upon the rate of interruption of the primary current.

The inductive effect is augmented by the presence of the iron core, with its alternate magnetisations and demagnetisations, which are in effect similar to rapid movements of a strong magnet alternately toward and away from the secondary windings.

The E.M.F. or voltage of the secondary currents will depend upon and vary directly as—

1. The **number of turns of wire** in the coil;
2. The **strength of the primary** current; and
3. The **suddenness of the break** of the primary.

The strength, quantity, or **ampèrage**, following Ohm's law, will vary **directly with those factors**, and **inversely as the resistance** of the secondary circuit.

1. A very long **secondary winding** may produce a very high E.M.F., with discharge sparks of great length; but its concomitant high resistance will prevent a great quantity of current passing, and the sparks will be correspondingly thin and thready.

Thus, the nature of the secondary winding must be decided according to the balance of those two factors deemed most suitable for the work to be undertaken. The relation is not really so simple as here stated, other factors complicating it; but discussion of those is not essential to a working understanding of the coil. Reference to the previous discussion of the most suitable current for exciting X-ray tubes (on p. 63) will explain the interest and importance of this point.

2. **Strength of the primary current** is, of course, under our direct control. Use of very heavy currents compels consideration of special points concerning self-induction of the primary winding, but those do not come within the purpose of this section, since such currents are prohibited by the use of a vibrating break.

With such a break it is said that a current of much more than 20 volts cannot well be used, since the platinum contacts will wear away too quickly and will have a tendency to stick, thus endangering the primary winding.

We have had good results with a current of 24 volts, and, with careful working, had little or no trouble; but probably we were very near the margin of the safe limit.

For X-ray work a coil should be supplied with about 200 Watts—say, 10 ampères at 20 volts—and the E.M.F. supplied should be at least 12 volts.

3. The **break** of the primary current should be as **instantaneous as possible.** The formation of a spark between the

contact points as they separate prevents the break being really instantaneous.

Various modifications of the mechanism of vibrating breaks have been devised to make the act of breaking contact as sudden as possible. Those are mentioned later; but more important in effect is the addition of a **condenser**, usually situated under the coil, and shewn there diagrammatically in Fig. 41 at *ee*.

It consists of a number of sheets of tinfoil, each insulated from the adjoining sheets by layers of paper soaked in paraffin wax. Alternate sheets are connected up, forming two sets, one of which is connected to each pillar (G and D) of the interrupter, and thus to different sides of the contact points at H. The condenser does not form a closed circuit, but its surface capacity offers a temporary diversion for the primary current entering at the foot of G, when its continuous passage is interrupted by separation of the contact points at H. Thus the sparking at H is diminished, and the suddenness of break correspondingly increased.

But the condenser has a further action in counteracting some effects of what is known as the **self-induction** of the primary.

Whenever contact is made or broken in the primary, each turn of wire in its winding has an inductive effect on its neighbours similar to that exerted on the secondary. Thus, at make there is in each turn a current induced in a direction opposite to the exciting current. This retards and weakens the primary current, and consequently **lessens the inductive effect of 'make'** on the secondary circuit. At break this self-induced current in each turn of the primary is in the same direction as the primary current; thus it augments the strength of that current, and concomitantly **increases the inductive effect of 'break.'**

But, while this adds to the desired effect, the appearance of an additional current at break **delays the cessation** of the primary current, and, consequently, the demagnetisation of the core; whereas we have already noted that the efficiency of the coil depends upon the suddenness of the interruption.

The action of the condenser in this respect is difficult to

explain in terms easy of comprehension yet technically correct, so we may take liberty with the latter in order to achieve the former condition.

The primary current was described as passing from A+, in Fig. 41, through pillars G and D, to the primary winding (*bb*); thus it may be supposed to pass upwards in that limb of the circuit adjoining the interrupter, and represented as vertical. Contact at H being broken, the current passes instead by *dd* to the distant side of the condenser. By influence of this charge the other side of the condenser (shown connected to the foot of pillar, D) receives an induction charge, thereby producing a current downwards in the vertical wire (*bb*). This is variously spoken of as 'absorbing the current in the

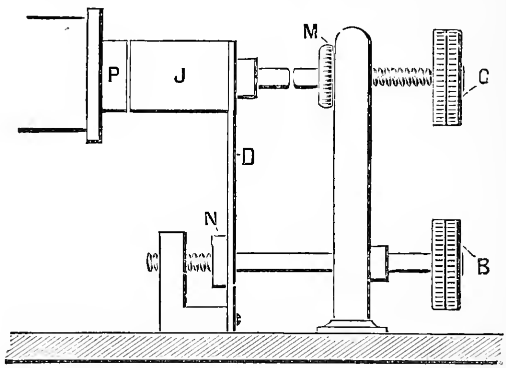


Fig. 42.

primary winding,' or as 'discharge of the condenser through the primary coil' in a direction opposite to the primary current.

The effect of this, however expressed, is to neutralise to a large extent the self-induction in the primary circuit on the cessation of the exciting current. It thereby **accentuates the suddenness of the break**, and hastens the demagnetisation of the core.

The break of the primary current is thus rendered so much more sudden and more powerfully inductive than the make that the latter may for many purposes be ignored, and the secondary discharge considered to consist of a series of inter-

mittent unidirectional impulses. As mentioned elsewhere, the 'reverse currents' due to 'make' come to demand attention when very high voltages (above 50 volts) are employed in the primary, but with vibrating interrupters certainly they may be ignored.

The Interrupter.—The two points to be considered in an interrupter are **duration of contact** and **suddenness of interruption.**

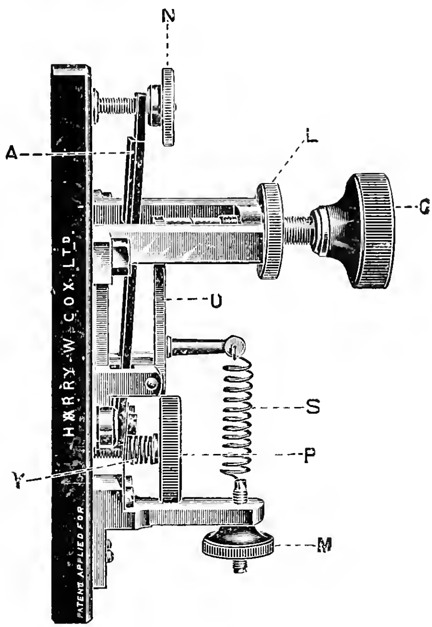


Fig. 43.

In the ordinary vibrating or hammer break, as shewn in Fig. 42, the spring (D) serves to hold the points in contact until the force of the magnetic attraction of the core (P) on the hammer (J) is sufficient to overcome the force of the spring.

A good interrupter must keep up contact of J with M, so that the circuit is closed long enough to enable the current in the primary and the magnetisation of the core to reach their maximum. This is referred to in earlier sectious as

'saturation' of the coil. With a low voltage this takes a correspondingly longer time.

Increase of the tension of the spring, by adjusting the screw (B), will prolong the duration of contact; but the more firmly the spring presses the platinum contacts together the slower will be the separation, and the less sudden will be the break of the current. To secure prolonged contact, associated with sudden break, a slightly altered construction is adopted by many makers. In most of these, as in the two illustra-

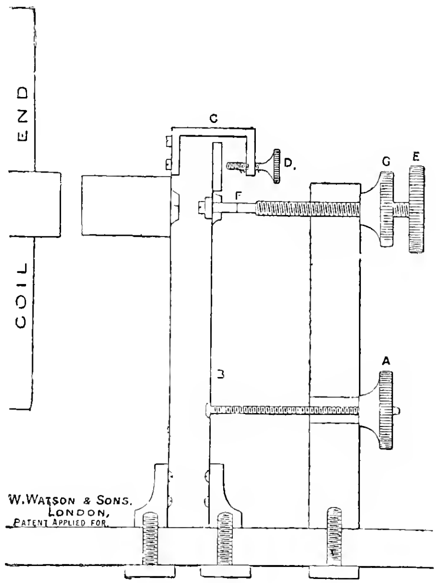


Fig. 44.

tions here reproduced (Figs. 43 and 44), the hammer and the platinum contact are carried on separate springs. In each the hammer has to move (by force of magnetic attraction against the restraint of its own spring) through the space between the screw (D, in Fig. 44) and the opposing face of the top of the spring (B) before a separation at (F) is effected. Thus, contact continues for some time after the circuit is closed, and 'break' takes place when the hammer has reached its greatest momentum. The speed of interruption may be

exactly regulated in such interrupters by adjustment of the screw (D).

For screen-work a fairly rapid rate of interruption is essential, and should be maintained even if intensity of illumination may have to be sacrificed somewhat; but for radiographic exposures with low voltage supply the rate of interruption should be kept somewhat low, so as to secure saturation of the coil and full intensity of discharge.

With even a rough understanding of the principle of a coil and interrupter there should be no difficulty in the practical working of suitable apparatus. A brief note of directions may, however, fittingly close this chapter.

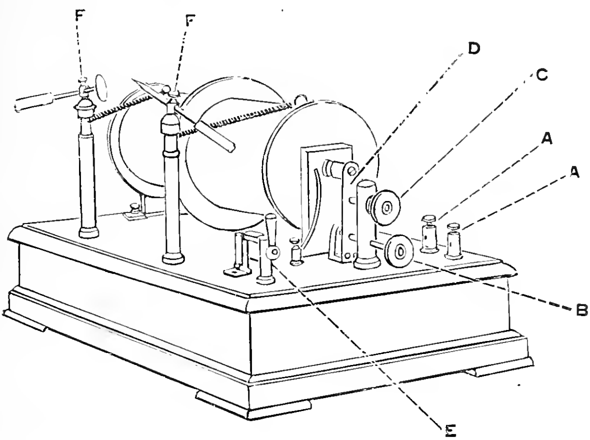


Fig. 45.

A A, Terminals for connection to source of supply; B, tension screw; C, contact screw; D, spring-carrying hammer; E, commutator or reverser; F F, discharging pillars with terminals for connection to X-ray tube.

Connections.—In Fig. 45, A A indicate the **terminals**, to which wires should be fastened to make connection with the primary source of supply.

Before doing so, see that the **switch or commutator** (E) is turned off—that is, in mid-position, with the handle upright, and the metal segments making contact with neither of the vertical spring-contacts on either side of it. That seen to, connect to each terminal (A A) an insulated wire, then

connect the other ends of those two wires to the accumulator or other source of supply—one to the positive pole or terminal, the other to the negative.

Next, to the terminals on the discharging pillars (F F) fasten wires, and connect one of those to each of the two end terminals of the X-ray tube, which should previously be fixed in a suitable holder. In a stationary set the relative positions of source, coil, and tube will be more or less constant, and the worker will come to know the proper connection for correct excitation of the tube. But in a portable set, or under varying conditions, the proper relations may readily be reversed; hence the starting switch at E takes the form of a commutator or current reverser. When set with the handle upright, as in the figure, this cuts off the current from the coil; when turned down to the right it completes the circuit, and allows current to pass in a certain direction through the primary winding; turned down to the left, it similarly allows current to pass in the opposite direction.

Adjustment of Interrupter.—If not previously attended to, the interrupter should now be adjusted before current is turned on. Referring to Fig. 42, on p. 72, the screw (B) should be turned to the right until the nut (N) is well clear of the spring (D) of the hammer. Then loosen the binding-nut (M), and turn screw (C) to the right until its point pushes the hammer (J) towards P. Between J and P there should be left about $\frac{1}{32}$ inch—enough space to allow an ordinary visiting-card to pass between them, and so that a small amount of play is possible to the hammer.

That space adjusted, hold C firm and tighten up the binding-nut (M), which should maintain the adjustment. Once properly set, this screw (C) should require no after-adjustment, unless when the platinum contacts may require attention.

Now turn down the handle of E so as to send a current in one or other direction through the coil. The tension of spring D being at present relieved, only a little current will pass between the contact points. Possibly the current passing may not at first be sufficient to excite the tube; if not, apply some pressure to the spring (D) by turning the screw (B) to

the left until evident excitation commences. At once inspect the X-ray tube to see whether the current is passing in it in the right direction, as evidenced by the apple-green fluorescence of the hemisphere in front of the antikathode and the freedom from illumination of the hemisphere behind. If the current be passing in the wrong direction, the fluorescence will be scattered irregularly over all the tube, and will appear to change in position, while the rays emanating from a tube under such conditions will be found to have very faint illuminating effect on a fluorescent screen, and to have little or no power of penetration. If the direction of current be seen to be wrong, then at once reverse it by turning over the handle of E to the other side.

It is very important to determine the direction of the current in the tube, and, if need be, to correct it, as will be understood from the earlier discussion of the action of X-ray tubes.

The current being now correctly directed, turn the screw (B) slowly towards the left. This causes the spring (D) to exert pressure on the contact points at H (Fig. 41), whereby the amount of current (ampèrage) passing into the coil is increased, and the illumination of a suitable tube caused to become brighter.

Unsteady illumination of a tube may be due to high vacuum—so-called 'hardness'—or to irregularity of the platinum contacts of the interrupter. If the former cause be excluded, the latter may be remedied by passing a fine file over the platinum; but this should rarely be required, since the platinum points usually burn themselves level. Should the platinum contacts for any reason stick together at any time, the current must at once be switched off from the coil.

CHAPTER IV

ACCESSORY APPARATUS

Switch-Board—Screen—Tube-Stand—Table—Diaphragms —Compressors—Protective Devices.

HAVING described the more essential parts of an X-ray installation, we have now to notice several accessory arrangements, whereby the operation of the apparatus is brought conveniently under control of the operator, and some whereby the radiation produced may be conveniently utilised for various purposes.

The **switch-board** forms, as it were, the key to the operation of any electrical installation, and so it is in X-ray work.

In the simplest plan of installation, where the full strength of available current is taken direct to an interrupter attached to the induction-coil, a separate switch-board may be dispensed with.

In such case a small switch attached to the base-board of the coil, with provision for reversing direction of the current, as shewn in Fig. 45, will serve most purposes.

But for regular serious work such an arrangement is quite inadequate, and we must have some measure of control over the various factors of our installation. To obtain uniform results under conditions inevitably varying, we must be enabled to modify our procedure to suit the conditions presented. Such means of control and modification are provided and conveniently grouped on a switch-board.

There are many variations in arrangement of the different units combined in a switch-board, but reference to the accom-

panying illustration will explain the principle of their construction and provide a key to similar arrangements. Fig. 46A represents the switch-board of the installation in West London Hospital. There, as mentioned earlier, we employ a continuous current supplied at 50 volts from a motor-generator working off an alternating main supply. All the items of the switch-board are fitted on a marble slab, with **resistance** coils enclosed behind, and the **interrupter**—of the dipper type—in a case below.

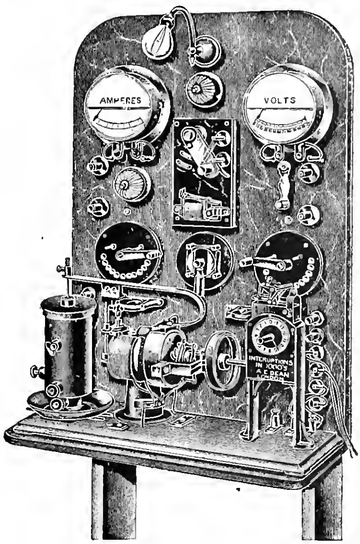


Fig. 46A.

To the left is an **ammeter**, measuring and recording the **strength of current** sent to the primary of the coil. This quantity is regulated by the device seen below, where a radial lever makes contact with a series of studs insulated from each other, and from the central pin carrying the lever. From the central pin passes a connection to the interrupter, and the peripheral studs are connected to successive points of a long series resistance, situated behind the slab, and connected to the supply from the generator. Thus, by suitably setting the lever, current may be tapped off at the point

corresponding to the strength desired. This was explained on p. 25.

On the opposite lower corner is a similar arrangement for regulating the current supplied to, and consequently the **speed of, the interrupter-motor.**

Above that is a voltmeter registering the **pressure** of the current supplied by the generator.

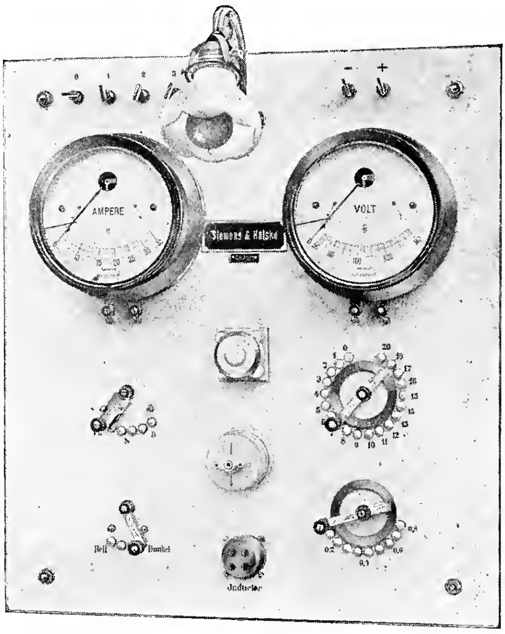


FIG. 46B.

In the centre of the slab is a **starting switch** of special design, whereby current is sent to the motor of the interrupter, setting it in action always before current is sent to the primary of the coil, as is done by further traverse of the switch-lever. This obviates the risk, mentioned in describing dipper-breaks, of sending the full uninterrupted current to the coil while the break is at rest. The electro-magnet seen under the switch-lever is connected with an arrangement for setting the switch to cut off after a predetermined number of interruptions. The other part of this arrangement is seen to the right

of the interrupter motor, but we seldom employ it in practice.

Under the starting-switch is a **commutator** or **reverser**, whereby the direction of the current may be altered, if necessary, to suit the setting of the X-ray tube. Where a valve-tube is employed in the secondary circuit, such reversal should not be called for; the X-ray tube should always be set in the same relative position, for only so can the valve-tube exercise its protective function.

At the top of the switch-board is a **lamp**, indicating whether current is passing to the board from the source of supply. Under that, and controlling its circuit, as also under and connected to each of the two meters, is a **small switch**; and on the side of the back casing are **safety fuses** to protect the various parts of the apparatus.

We find this a highly efficient and convenient arrangement, and it represents the proper average control compatible with efficiency, while avoiding complication.

The indications for varying the different factors, as here provided for, are given in the sections discussing operative procedure.

Fig. 46B illustrates another typical switch-board for continuous current circuits of from 65 to 130 volts for use with outfits having a triple Wehnelt interrupter.

Fluorescent screens, as mentioned in the introductory notes, are necessary to reveal the X-ray effects directly to the eye of the observer. They are commonly made of a deposit of platino-cyanide of barium on suitable material—usually vellum—stretched on a light wooden frame.

The fluorescent material is, when new, of a yellow colour with a greenish tint. This latter tint becomes lost through prolonged exposure to X rays, and the yellow assumes gradually more of a brownish tint, in which condition fluorescence is considerably diminished. Occasional exposure to daylight is beneficial to screens.

To observe the image on a screen properly the observer must be in darkness, and it will be found of advantage to let the eyes become accustomed to the darkness for a little before an attempt is made to view the screen, the retina becoming

thus more sensitive. Dark boxes, with a fluorescent screen at one end and an eye-shade opposite, are made for use in daylight, but these are inconvenient in use, and no work should be ordinarily undertaken unless in a room capable of being darkened at will.

For diagnosis of gross lesions and localisation of foreign bodies a screen examination may be all that is required; but we may mention here a point that will be further impressed later—namely, that negative evidence can rarely be relied on from **screen examination** alone, but **should be checked by a radiogram.** This latter may reveal finer points not discernible on the screen, and even fractures have, for want of this corroboration, been overlooked, the absence of displacement masking the actual lesion (see Fig. 69).

Screens are made in various sizes, and vary proportionately in price, but for general work a screen should be large enough to include readily in one view the apices of both lungs of an adult person. A larger size will seldom, if ever, be wished for, and, having one such screen, there is no necessity for a smaller one.

It is advisable to have the fluorescent side of the screen covered by a sheet of superleaded glass, which will protect the surface from injury, and further protect the face of the observer from injurious effects of the radiation.

Metal handles to protect the hands while holding the screen are sometimes also attached to it, but where gloves are worn, as advised, this is superfluous.

A **tube-stand** for holding and permitting adjustment of the X-ray tube should, above all else, be **firm.** For this reason a stand is preferably somewhat massive, and should have a heavy base or foot. This base will be steadiest on an ordinary uneven floor when arranged with three points of support. Most stands on the market are much too flimsy and shaky, being designed apparently with a view to lightness, but this quality is of no practical importance unless for portable apparatus.

Fig. 47 shews a design we find very serviceable, but the accessories attached we set as in the arrangement shewn in Fig. 40. Stands are best made with a metal base for steadi-

ness, the remainder being of wood, so as to avoid short-circuiting, and they should be of sufficient height for all possible purposes. The means of adjustment should be simple, as otherwise stability may be interfered with; and

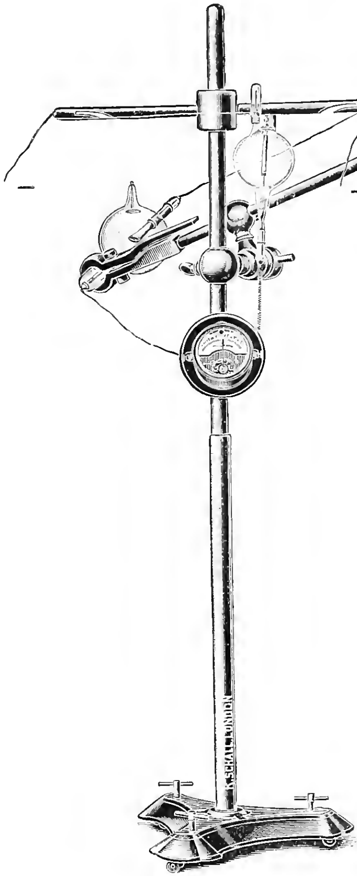


Fig. 47.

care should be taken in adjustment that the X-ray tube is kept always as near the supporting upright as may be compatible with the position desired.

Most recent stands are made with some form of protecting enclosure for the tube, but as we do not recommend this

position of the tube for radiography, we consider such elaboration somewhat superfluous for occasional use.

For **therapeutic purposes** a **special stand** should be provided. This may be of metal, since its position can usually be fixed with respect to the connecting wires, and need not be altered. This stand should be specially adapted to carry a

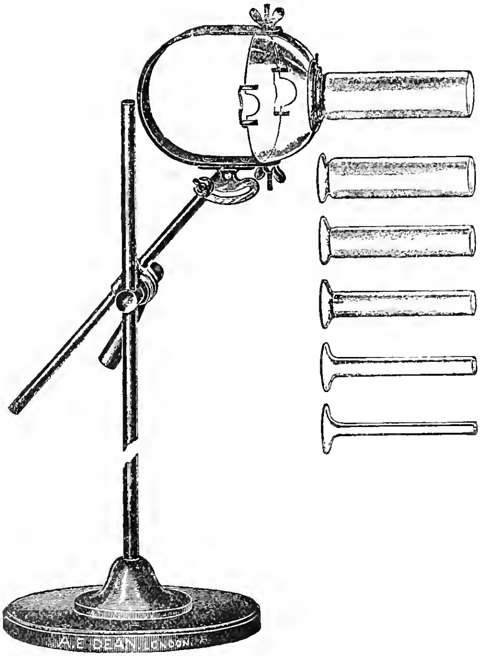


FIG. 48.

shield for protection of the operator, and of parts of the patient other than that on which the effect of the radiation is desired.

From the adjoining figure (Fig. 48) will be seen the design of the form of shield found most useful in our practice. The shield is made of special superleaded glass opaque to X rays, and a series of tubes or funnels of similar material and varying diameter are provided to fit on the front of the shield. Those funnels as figured are made of a standard

length of 8 inches, but can be obtained shorter if desired, the length determining the distance of the part from the X-ray tube during exposure. We usually employ funnels of a length of 3 inches, so that their outer end is 6 inches from the anode of the tube (see p. 233). By choice of a funnel of appropriate diameter a larger or smaller area may be exposed, while the surrounding tissues are protected. This does away almost entirely with the clumsy method of protection by sheet-lead, and, the funnels being readily sterilizable, there is

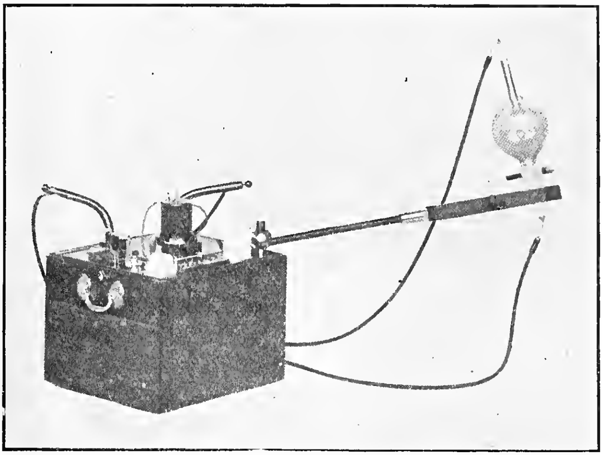


Fig. 48A.

no objection to their repeated use. Modifications of this have been made, and some are made applicable to radiographic work also, but the general idea is the same in all.

Stands or **cabinets** are designed to accommodate break, coil, tube-stand, and other X-ray apparatus, so that they may be moved about complete and ready for connecting to a source of supply, but only under exceptional circumstances could we consider this expensive and inconvenient arrangement justifiable. Fig. 48A represents a special portable outfit designed for use in isolated places; it is operated by means of a small battery of accumulators chargeable from the nearest private plant, or, failing this, by means of horse-gear or bicycle-gear (see p. 47). Where regular X-ray work is done, a room

will be devoted to the purpose, and will be fitted with pieces of apparatus arranged in the most convenient manner for operation. Even where the apparatus is only used occasionally, it will be found better to fix the separate units as found convenient to the special form and other contents of the room. Where portability is of prime importance, the parts may be more easily conveyed separately and temporary connections made, unless in so far as convenience of packing may

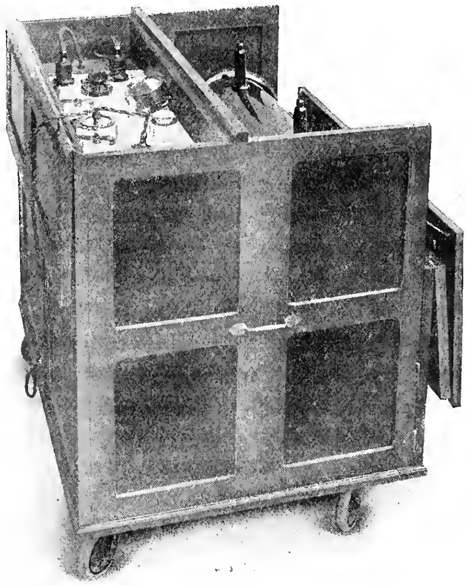


Fig. 48b.

dictate some arrangement in a suitable box. Where it is desired to do much bedside work—as in a surgical ward—a movable trolley, carrying motor-generator and all other necessary apparatus, may prove very serviceable. Fig. 48b represents a recent design of such a set, which may be connected to any ordinary wall-plug of an electric-light installation.

The **table or couch** is a piece of apparatus of prime importance for convenience in X-ray work. The best tables are

undoubtedly those made with a **top of material transparent to the X rays**, while the X-ray tube is carried underneath in a suitable box or holder, which may traverse the full length and breadth of the table as well as allow adjustment perpendicularly. On such a table the patient may recline in any suitable position, while the tube is moved opposite to any region desired to be examined, the fluorescent screen being placed above. A comprehensive screen examination may thus be made in a short time, and with a minimum of inconvenience to patient and operator. Then at any desired point the tube may be fixed, and a photographic plate substituted for the screen if a radiogram be desired. The previous viewing by the screen insures finding on the plate precisely the part indicated.

Many points of detail will naturally vary in different designs of such tables, but in the one we here describe we have found all the points carefully considered. After prolonged experience and adaptation of parts, we consider it the most reliable and comprehensive design on the market, and we feel we can safely recommend it for general X-ray work, where simplicity and strength are also of prime importance. In this, as in all other apparatus, the two chief aims to be kept in view are **simplicity** and **adaptability.** Where these conflict, a compromise must be attempted; but it is the common mistake of instrument-makers and specialists to lose sight of the first in elaborations to serve the second, and especially is this danger present where it is desired to employ one piece of apparatus for several different purposes. When we state that with the table under review we are able to do screen-work, radiography of any part of the body from above, below, or either side, stereoscopic work, and orthodiagraphic work, it will be admitted that its capacity for use is comprehensive enough, while the annexed sketch (Fig. 49) will sufficiently demonstrate its simplicity.

The **main body** of the table consists of a strong wooden frame supported at the four corners, leaving the full length free for traverse of the carriage bearing the X-ray tube and possibly the fluorescent screen. On this frame is stretched a strong sheet of **canvas transparent to the X rays**, and this

can be tightened when necessary by small screws along the side, as shewn at A A in figure. The **travelling carriage** consists of a box (B) under the table and a framework (C) above, which two parts are connected by lateral uprights (H), and move together on small rollers running along a horizontal guide (D) on either side of the table. The **tube-box**, as illustrated, consists of a wooden framework with sides of glass, which is impervious to X rays, while allowing the operator a free view of the tube to note its action. The box is adjustable vertically on the supporting guides (E), and the supports for

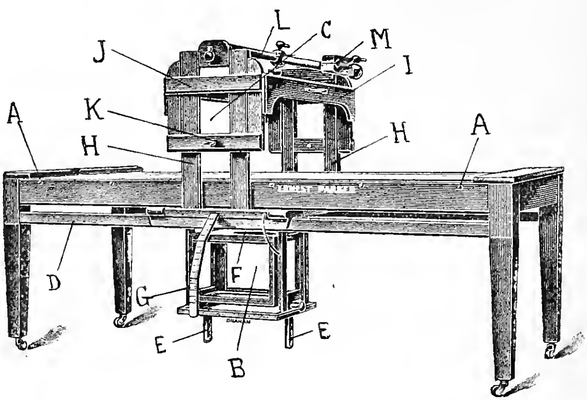


Fig. 49.

Since the above block of our table was prepared, we have substituted for the wooden tube-box under the table an arrangement with a large protective glass dome, affording more adequate protection to the operator. Adjustment of the tube is by the same arrangement made more convenient. The upper part of the carriage is now made easily and completely detachable, leaving a clear top to the table when that part is not required.

the tube at either end (not shewn in figure) are adjustable vertically and horizontally so as to get the tube properly set and centred.

On the upper side of the box is situated centrally an **iris diaphragm** at F, the value of which will be explained later, when photography is under consideration (see also Fig. 52).

The box can be moved transversely to the table on small rollers resting on horizontal guides, which are rigidly fastened to the uprights (H).

This transverse movement is controlled and measured by a jointed arm (G), on which a scale is marked corresponding with a scale marked on one of the transverse bars (I) of the upper part of the carriage, and referred to later. Thus it will be seen that the tube can be moved readily to any position within the borders of the table.

For ordinary purposes the screen will be laid directly upon the part to be examined, and will be moved about directly by hand as required, since it is important to have the screen as closely apposed to the part as possible, and a view is often desired at varying angles. In **orthodiagraphic work,** however, as applied by us to this table, it is necessary to have the screen move in all directions precisely with the lamp. For this purpose a special upright (Fig. 119) with two horizontal arms is added, one of which horizontal arms is substituted for the hinged rod (G), and the other connected to the screen. The screen lies meanwhile inside the frame (I J), and is free to move between parallel guides transversely as actuated by this added connection, while it moves longitudinally with the frame. The use of this and another small addition for the purpose of making a record of the orthodiagraphic shadow will be further referred to when the subject of orthodiagraphy is considered (see Chapter IX., p. 209).

The part **above the table** consists of a frame (I J), which may be moved vertically on the connecting uprights (H), or clamped by screws (K) at any desired height. This may serve for **carrying a fluorescent screen,** being gauged to fit the ordinary size of screen when placed on rests in its open part. It may further serve as a **compressor** or steadier of a patient, though we find this practice seldom called for. On one of the transverse bars (I) of this frame a scale is marked on either side of the centre of the table's width, so that by noting the number opposite any point of a patient's body the tube may be placed exactly under that point by setting the arm (G) to the same number on the scale it carries.

Across the top of the uprights may be placed a horizontal bar (L) carrying a **tube-holder** or clamp (M), in which a tube may be placed when it is desired to take a radiogram with the plate under or at either side of the patient as he lies

on his back or face. This last item is seldom called for, as nearly all radiograms can be better taken with the tube below. In the rare cases in which exposure with the tube above is desired a separate tube-stand will usually be at hand, but the inclusion of this part makes the table complete for all purposes, and in no wise complicates the other parts.

The reasons and uses for those various devices will be evident when we come to consider practical working, and from this description the reader should recognise the points to be looked for in a serviceable X-ray table.

Diaphragms are contrivances interposed in the zone of radiation emanating from an X-ray tube, so as to cut off from a sensitive plate under exposure unnecessary rays, which would otherwise serve to confuse the record and blur the outline of the picture obtained.

In discussing X-ray tubes, it was pointed out that radiations were emitted from a small focal area of the antikathode. From that they proceed in straight lines, which collectively form a divergent cone, as shewn diagrammatically in Fig. 50. Thus the projected shadow of any object interposed across their path will be a magnified and distorted image of that object, according to its position relative to the tube and sensitive plane receiving the impression. This is discussed more fully in the sections on 'Interpretation' (p. 124), 'Localisation' (p. 132), and 'Orthodiagraphy' (p. 210), and hardly requires demonstration; but the point will be made clear by reference to the annexed figure (Fig. 50).

There M N is supposed to be a sensitive plane—fluorescent screen or sensitive plate—receiving the rays emanating from an X-ray tube below. The rays pass through equidistant points on the plane A K, which, however, lies at an angle to the plane M N, this being the more common condition of objects exposed in practical radiography. The magnification of A K at M N is readily evident, and the distortion is represented by the inequality of the distances between the projected points A′, B′, C′, etc. On the larger scale of actual working conditions this effect is proportionately more marked, though the inclination of A K is here made somewhat extreme for the purpose of clearness.

The distortion is greater in the parts exposed to the more divergent rays, and is relatively negligible only for a small area on each side of the central ray (X Y). Thus, in a radiogram of a large area, while the central parts will be represented with some degree of accuracy in proportion and relation, the image of the marginal parts will be so magnified and distorted as to be of little or no real value.

Further, from the walls of the X-ray tube, and from other metal parts than the target, emanate irregular rays, sometimes

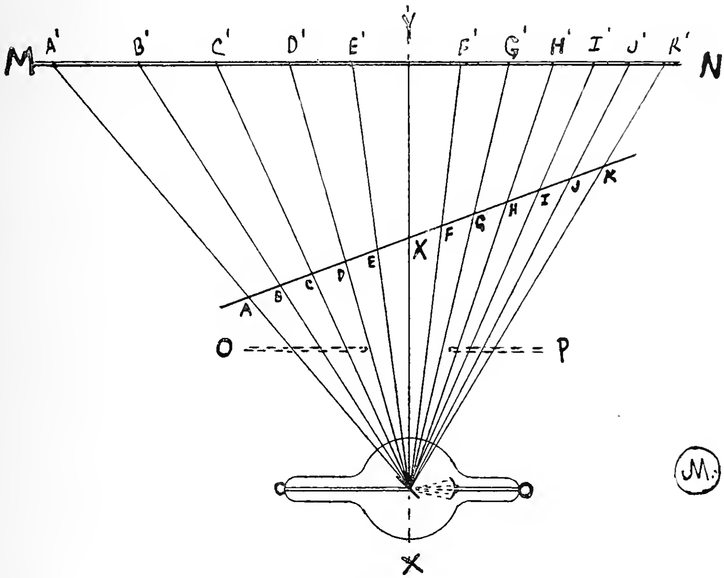


FIG. 50.

called 'secondary' X rays. These are due to our inability to confine the origin of kathode rays strictly to the kathode, or to bring to a focus all the rays formed there, as at its edges. Those irregular kathode rays, on their impingement on the walls of the tube or other parts in their path, give rise to X rays, which from their irregular origin and distribution serve to confuse the projection of the regular radiation.

These secondary X rays are doubtless responsible for much of the general fogginess of negatives, and for the lack of

sharpness in outline and of definition in detail so frequently noted on screen or radiogram.

If a diaphragm opaque to the radiation (usually of lead or

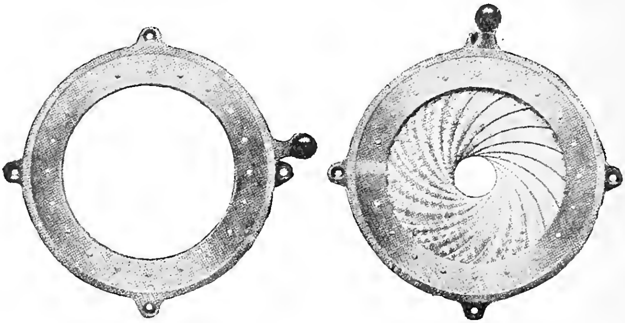


Fig. 51.

zinc) be interposed between the tube and the object exposed, as at O P in Fig. 50, the marginal distortion referred to will be to some extent obviated by limiting the view to more

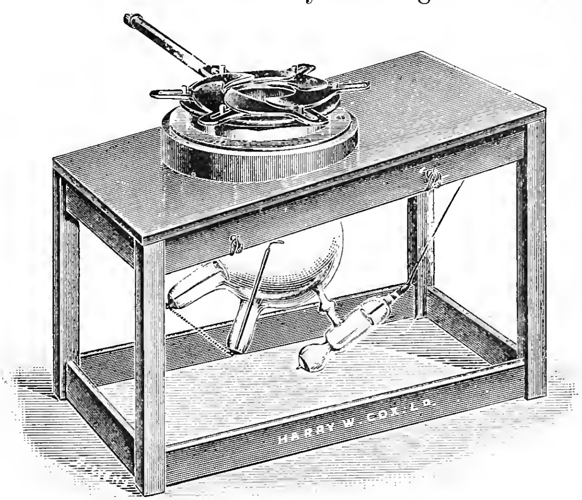


Fig. 52.

central parts, and definition of outline and detail will be improved by cutting off much of the secondary radiation described above.

Fig. 51 shews an adjustable flat diaphragm suitable for attachment to a tube-box.

Fig. 52 shews a more simple but quite efficient arrangement fixed to the top of a tube-box, as described for working with the X-ray tube under the table, which we consider the most convenient and efficient method.

In both figures the diaphragm shewn is of the iris pattern, similar to those employed in most ordinary photographic cameras. This, by means of a projecting handle, may have its circular aperture adjusted concentrically to any

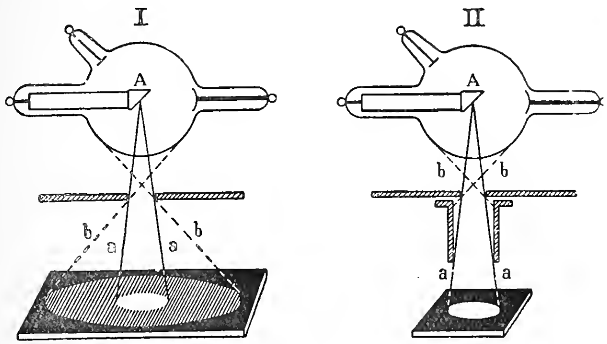


Fig. 53.

desired size, and, situated below the patient, can be so adjusted while the effect is noted on a fluorescent screen above.

Unfortunately, those diaphragms cannot cut off all the secondary rays, but they will cut off those of greatest obliquity, which otherwise would naturally cause most confusion of result.

Recently another form of diaphragm has been introduced and commended in connection with the compressors discussed in the following section, and illustrated in Fig. 54.

In Fig. 53 we reproduce two diagrams, intended to represent the advantage of those 'cylinder diaphragms' over the flat or disc form.

The diagrams certainly demonstrate that by use of a cylinder diaphragm radiations will be cut off more effectually

from the surrounding area, and a frame of denser contrast will be obtained for the desired view.

But we are not concerned about the excluded area ; it is the area of desired exposure we are anxious to improve. To that area secondary rays will pass as freely through the cylinder diaphragm as through the disc, so that we cannot admit the superiority claimed for the former while they are much less convenient to use. Adjustment of the size of area to be exposed necessitates for each change the substitution of a separate cylinder of appropriate diameter. The determining aperture, being farther removed from the tube, requires a large diameter, and the larger sizes of cylinder become cumbrous. With any cylinder, large or small, the tube must be accurately centred at the end, or the illuminated area may resemble any of the other phases of the moon rather than the full round phase desired. This is further referred to in the succeeding section, in which the use of compressors is considered.

A disc iris diaphragm is light and compact, and with an opening variable from about 1 to 3 inches it is available for all exposures by simple adjustment while fixed in position. Placed close to the X-ray tube, a small aperture only will be required for most purposes, and the disc will there intercept as many of the cross rays which fog and blur the desired image as will a much less convenient cylinder.

The use of a diaphragm is further referred to briefly in the chapter on photography (p. 107).

Compressors.—In order to inhibit movement, and to secure closer apposition of the plate to the part to be radiographed, especially when such part is deeply situated, many workers employ some form of compression.

In abdominal work principally is this employed for determining presence of calculus in a kidney. Though we do not commend any of the elaborate compressors listed by instrument-makers, we may briefly describe their principles and mode of use. All of them exert pressure on the abdomen, whereby diaphragmatic respiration is restricted and the concomitant movement of the kidneys minimised.

The simplest form is a strap or binder passed from one side of the table to the other so as to cross over the abdomen of

the patient whilst he lies on his back. This strap may be tightened by ratchet or other arrangement at one side of the table, and, in addition, an inflated rubber bag may be placed between it and the patient's abdomen.

Fig. 54 shews a more elaborate arrangement, which combines with compression the advantages of a cylinder diaphragm. This, presumably, confines the illumination to the desired area (as described in preceding section), but that result depends on previous very careful setting of the tube and direction of the cylinder.

A similar diaphragm compressor may be fitted under the upper part of the travelling frame of such a table as is

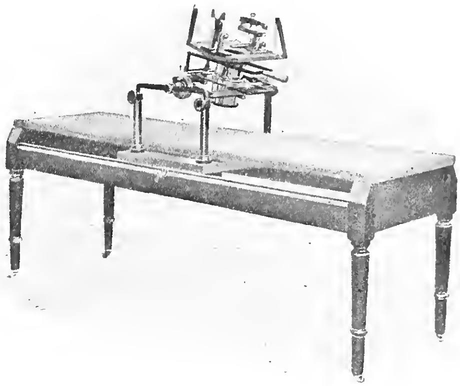


Fig. 54.

described on p. 88, or a simpler arrangement, as shewn in Fig. 55, might be adopted.

Our objection to all these methods is that they involve setting the X-ray tube above the patient. This position does not allow of previous screening of the part in the position chosen for making a radiogram—unless, indeed, at very great inconvenience, which renders it impracticable. As explained in another section, this possibility renders the position of the tube under the patient preferable; for, with the tube below and screen above, the area illuminated can be directly viewed, the tube set and the diaphragm adjusted as seen to be most suitable. Then, without moving patient or tube, a

sensitive plate may be substituted for the screen with a certainty of having impressed upon it the view previously selected.

With a cylinder diaphragm the tube must be carefully set before the compressor is put in position. But when set in position, as in Fig. 54, even if the tube be properly adjusted and the end of the cylinder be set on the front of the body correctly, a slight wrong inclination of the apparatus may direct the rays so as to illuminate quite the wrong area of the lumbar region. As already explained, such an unfortunate contingency is obviated by previous screening, with the tube

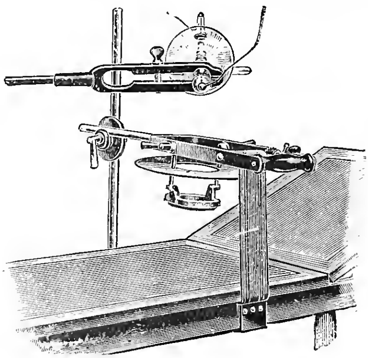


Fig. 55.

set below the patient; hence we prefer this latter position of the tube for radiographing the kidneys, as well as for all other parts admitting of its adoption.

For compression of the abdomen we employ an inflated rubber bag, which is placed under the patient, as shewn in Fig. 56, whilst he lies face downwards on a table with trans-radiant top and with the X-ray tube set below.

The weight of the patient acts as a sufficient compressing force to inhibit, as far as possible, abdominal movements; or that force may be augmented by placing weight on the rigid board which is placed above the sensitive plate as it lies over the lumbar region. The details of setting for radiography of the kidneys are explained later in the chapter on diagnosis (p. 183).

For other parts we do not employ special means of compression.

Usually on the plate, as it lies over the part to be exposed (the tube being below), we place a flat board faced with sheet-lead which is of weight sufficient to steady the part, and on that we may exert manual pressure according to the capacity of the part and person to bear it; but we do not recognise the necessity of mechanical compressors. Possibly part of the improvement in results claimed by some workers for them may be properly ascribed to their use, especially since the position of the tube above the part does not allow of steadying the part by any other means; but we are more inclined to

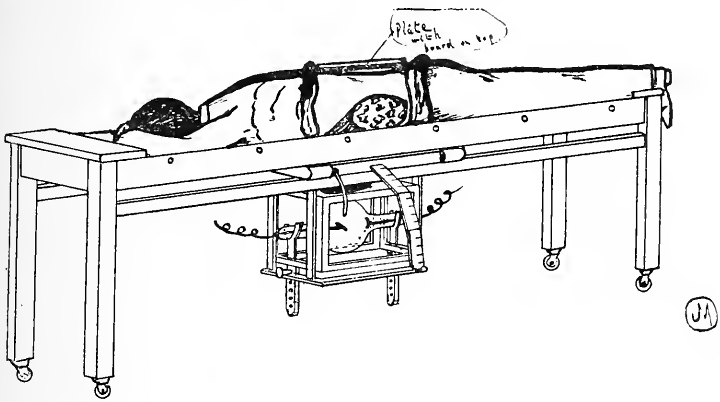


Fig. 56.

think that the zeal which includes this detail of method will at the same time be enforcing precision in other details which will more truly account for the improvement noted.

The principles of inhibition of movement and closest possible apposition of the sensitive plate to the part exposed are worthy of full observance, but we think they can be sufficiently applied without special, and too often expensive, apparatus.

Gloves and other protective devices are commonly used by X-ray workers to protect the hands and other parts from dermatitis producible by prolonged or repeated exposure to the rays. All care should be taken to avoid undue exposure of any

part of the person of the operator to the direct rays. Much can be done in this direction by seeing that the X-ray tube is set with illuminated hemisphere directed away from that part of the room in which the operator takes his position during long exposures—therapeutic or radiographic. Use of the therapeutic shield described in a previous section will be serviceable in this direction, as well as serving its direct purpose of protecting the patient from exposure of parts other than that desired to be acted upon. (In later designs those shields are made deeper than shewn in Fig. 48.) Enclosure of the X-ray tube in a box of glass or other material opaque to the rays will also protect the operator during screen and photographic work. An ordinary wooden box made with suitable apertures may be used if made X-ray proof by lining with ordinary white-lead putty, which is cheap and serves well.

It is in screen work that the principal danger of exposure exists, and during such work an operator should always have at least his hands protected. Gloves of thick rubber impregnated with lead should be worn for handling the screen, and a hint worth remembering when consulted about a patient by a practitioner eager and anxious to 'see for himself,' is to allow the practitioner to hold the screen in position during what will probably be an unduly prolonged illumination.

The danger to the patient of such prolonged screen examinations must also be borne in mind, as also the danger involved in taking a series of radiograms of the same part, especially if the tube be soft.

As to the protection of other parts of the operator opinions vary. Reports have been made that many X-ray workers have been found sterile owing to unconscious exposure of the testicles to radiation, and experiments on animals seem to demonstrate that the X rays probably have an arrestive action on the special functions of the generative organs.

The conditions and degree of this effect still await investigation, but meanwhile it is certainly advisable that anyone exposed much to X rays should wear an apron of rubber prepared like the gloves. Smaller testicle covers to wear concealed by the clothing are also made.

Protection of the patient from undue exposure is equally

necessary, and has been referred to briefly in this section, but will be more appropriately discussed in full in the later section on ‘Therapeutics.’

Other small pieces of accessory apparatus are discussed under the headings appropriate to their use in therapeutics, radiography, etc.

CHAPTER V

PHOTOGRAPHY

For success in radiography it is essential that the operator should have intimate knowledge of the installation with which he is working, and for which he must ascertain for himself the conditions of highest efficiency.

The various factors involved have been discussed under the heading of 'Apparatus.' The questions of supply, interrupters, and induction-coils being thus understood, we now note some points requiring attention in the actual production of a radiogram.

The most careful attention must be paid to every detail of the process; no point, however minor, is unworthy of attention if the best results be desired.

I. Choice of Tube.

It has been already explained how tubes vary in hardness and in consequent power of penetration.

It was noted then that a tube should always be chosen with due regard to the nature of the work to be done.

For photographic work a tube is selected of a hardness in direct relation to the density of the part to be exposed.

This factor will be seen, from the following table, to correspond roughly to the actual thickness of the part, but noteworthy exceptions occur in the case of radiograms made of the kidney or bladder, in which instances the presence of calculus is the usual point to be settled.

In each of these cases, if a tube were used corresponding in hardness to the thickness of the part, the rays would probably

penetrate the calculus, and leave no discernible trace of its existence on the sensitive plate.

The following table indicates the quality of tube we have found suitable for radiographing different parts. Added to it is a table of exposure times, which will be referred to in the following section. We are pleased to find that the majority of experienced workers agree with us in using softer tubes than have been used formerly. A minority hold that harder tubes allow reduction in exposure time, and though the resultant negatives are very thin in quality, and therefore unsatisfactory for direct examination, that from them excellent bromide prints may be made.

(*Continued on next page.*)

EXPOSURE TIMES.

(*See later explanatory notes.*)

TUBE SET AT 10 INCHES FROM NEAREST SURFACE OF PART.

	Parts in Order of Density.	Using Mercury-dip Break. 6 to 10 ampères at 50 volts =300 to 500 Watts.	Using Wehnelt Electrolytic Break. 10 to 20 ampères at 80 volts=800 to 1,600 Watts.
A *soft tube*, giving spark of from 1 to 2 inches, should be used for—	Fingers.	30 seconds.	10 seconds.
	Toes.	30 ,,	10 ,,
	Fore-arm.	60 ,,	20 ,,
	Calculus in kidney.	3 minutes.	1 minute.
	Calculus in bladder.	3 ,,	1 ,,
A *medium tube*, giving spark of from 2 to 4 inches, should be used for—	Wrist.	1 minute.	20 seconds.
	Upper arm.	$1\frac{1}{2}$ minutes.	30 ,,
	Elbow-joint.	2 ,,	40 ,,
	Foot.	$1\frac{1}{2}$,,	30 ,,
	Lower leg.	2 ,,	40 ,,
	Ankle-joint.	2 ,,	40 ,,
	Thorax.	3 ,,	1 minute.
	Clavicle.	3 ,,	1 ,,
A *hard tube*, giving spark of from 4 to 6 inches, should be used for—	Shoulder-joint.	3 minutes.	1 minute.
	Knee-joint.	3 ,,	1 ,,
	Femur.	3 ,,	1 ,,
	Hip-joint.	4 ,,	$1\frac{1}{3}$ minutes.
	Spine.	3 ,,	1 minute.
	Pelvis.	4 ,,	$1\frac{1}{3}$ minutes.

We prefer, however, to depend upon the negative for comparison of results and clinical observation; and we demur to the introduction of unnecessary art into the radiographic process, already complicated by many uncertain factors.

For **foreign bodies** in the tissues or body cavities the tube must be chosen of hardness suitable for the material of which the foreign body consists.

II. Exposures.

A tube of hardness corresponding to the part to be radiographed having been selected, the duration of exposure now depends mainly upon two factors—(*a*) the current supplied, and (*b*) the distance of the X-ray tube from the sensitive plate.

(*a*) **Current supplied.**—This is most conveniently spoken of for purposes of comparison in 'Watts'; that expression of power being equivalent to the product of the quantity of current supplied, as expressed in ampères, multiplied by the electro-motive force expressed in volts.

It will be readily understood that the more powerful the current supplied, the shorter will be the exposure required, other conditions remaining constant. Reference to the table on p. 101, where exposures are quoted for two different supplies, will illustrate this point and give a guide for early practice.

(*b*) **Distance of Tube from Plate.**—As with all radiations, the effect of X rays on any object varies inversely as the square of the distance of that object from the source of the rays. Thus duration of exposure will vary directly as that factor.

A convenient rule for regular work is to set the X-ray tube at a distance of ten inches from the nearest surface of the object to be radiographed. The table of exposures on p. 10 is based on work done under this convention.

Effects of Different Exposures.—Penetrative power must not be confused with actinic effect. No variation of exposure will compensate for failure to choose a tube suitable to the special part to be radiographed.

Thus rays from a hard tube will penetrate a hand, and fail

to give definition or detail, however short the exposure may be; whilst a soft tube will fail to penetrate or define a hip-joint, though the exposure be ever so prolonged. Keeping this in view, we shall be understood when we dissent from the prevailing 'lust for speed' in exposure, which is revealed in present-day literature of radiography. We advisedly say 'in the literature,' for we fancy most of it exists there and not in regular practice; whilst instrument-makers are naturally apt to boom an idea likely to involve alterations in existing apparatus.

The exposures we have quoted in the foregoing table are those we have found to give uniformly good results under actual everyday working conditions, and which we employ for all purposes for which radiograms are ordinarily desired.

We are aware of certain advantages claimed for short exposures, especially of the thorax, but in our experience it is possible to obtain quite satisfactory results in practically all cases, without such sensational methods as are advocated to discount physiological movements.

With a current of 25 ampères, at a pressure of 120 volts, passed through an electrolytic interrupter, we have repeatedly made radiograms of adult chests in five or six seconds, but we cannot recommend the practice.

With such heavy currents the latitude in exposure is very small, failures and difficulties with the apparatus are frequent, special X-ray tubes are required, and these have but a narrow margin of safety in working; thus very rapid work, though possible, is most inconvenient and expensive.

Further, as has been already mentioned, with such short exposures the same detail of structure cannot be obtained as with longer exposure. See note on Teleradiography on p. 219.

This is especially important in considering everyday exposures for investigation of bones of limbs, many of them but partially ossified. Shortening the exposure of these to any marked extent would probably produce radiograms with fair outline, but with detail of structure—normal or pathological—quite indefinable. Thus the purpose of the process may be entirely missed through an attempt at its elaboration.

Where there is doubt as to the correct exposure for a certain

set of conditions, it should be remembered that an over-exposed plate may, to a certain extent, be dealt with by precaution in development, whilst an under-exposed plate cannot be so remedied. Therefore, within reasonable limits, let the exposure be ample and development cautious.

Towards the end of a long exposure with a hard tube we have found it a good plan to strengthen the current, so as to produce some heating of the tube, and consequent softening. This seems to add to the outline picture produced by the rays of higher penetration some detail of structure otherwise lost.

III. Position of Patient and X-Ray Tube.

Much depends on the choice of a proper position of the patient and correct setting of the X-ray tube and sensitive plate.

No exposure should ever be made before each point has been carefully considered and attended to; haphazard work can only result in disappointment.

In deciding the best positions the necessity for **steadiness** of patient and apparatus must be observed. It is of no use arranging a patient in an unsteady position, which he can only maintain by muscular effort, for that is almost certain to relax more or less, and permit movement of the part exposed. Steady support of the tube was enjoined when speaking of tube-stands, and is an essential readily understood.

A universal rule in deciding relative positions of X-ray tube, patient, and sensitive plate is to **get the plate as near as possible to the object** or part of which a view is desired. If exposure must be made through the thickness of a part, then the plate should be placed on that side of it on which the lesion is suspected, for, as will be seen later, the parts nearer to the plate are defined relatively more clearly.

For each part of the body commonly radiographed a **standard position** should be decided on, and unless special circumstances indicate otherwise, all exposures of the part should be made in that position, for the sake of comparison with similar exposures either directly or in the mind of the operator.

Clothing, Splints, Plaster, etc.—It is preferable to have the part of the body denuded of **clothing** when a radiogram is to be made of it.

Most textures obstruct the X rays but little, and outlines of bone can easily be defined through ordinary clothing. Such a view may, under special circumstances, be advisable and sufficient, but detail of structure cannot be defined under such conditions.

After a **splint** has been applied, a view of the part is often desired to ascertain whether displacement of the bone is accurately reduced.

It is, indeed, a rule with many surgeons that every fracture must be so viewed before it is considered to be 'set.' Through ordinary wooden or poroplastic splints a satisfactory view of a limb can always be obtained or a radiogram made; metal splints make either impossible, unless, indeed, in a direction passing between the splints.

On wooden splints strips of metal may interfere and limit the possible views. A method of avoiding this obstacle, as commonly met with in splints on the lower leg, is described later, in Chapter VIII.

Plaster is always more or less a hindrance to X rays, and the strong adhesive plaster with a lead basis, which is employed by many to bind splints in position, is especially so, but the information desired can usually be obtained despite this. Even through a thick casing of plaster of Paris a radiogram of a limb can be made, and will probably indicate clearly enough the position of fragments of a fracture or degree of reduction of a dislocation.

Dressings of preparations containing iodoform, bismuth, mercury, or lead are opaque to X rays, and should always be removed when possible.

Where such preparations have been absorbed into the skin, radiograms of the part may be affected by their presence.

When splints, plaster, or dressings have to be kept in position, and are interposed in the path of the rays, a harder tube than would otherwise be necessary should be employed, and it should be set a little closer than usual.

X-Ray Tube above the Patient.—This is the older arrangement for making radiograms, and though, in our opinion, much inferior to the method of exposure from below, circumstances occasionally do not permit of choice. Thus, for bedside work, or on other occasions requiring portable apparatus, it is usually the simpler and quite satisfactory method. In such a case, the part to be radiographed should be supported on some firm, flat surface on which the sensitive plate may lie. It is a very good practice to lay on a firm support a flat board faced with sheet lead.

Besides furnishing a flat surface on which the plate may with safety lie even with some superimposed weight, the lead in apposition to the plate seems to sharpen the definition of the radiogram, though this latter effect, we admit, may be more apparent than real.

The part should be arranged on this in the most convenient position, and having turned downwards that aspect of which it is desired to have the most distinct view. Thus, if a picture of the sternum be desired, the patient should be placed with his face downwards; if a picture of the spine, then he should lie on his back.

The X-ray tube must now be set directly over the centre of the part to be radiographed, and at a distance of about 10 inches from its upper surface. This alignment is secured by viewing the tube and part from two positions at right angles, and adjusting the former till it is seen to be vertically over the centre of the part. A plumb-line may be dropped from the tube to guide its setting, but this is seldom necessary.

The tube being thus set, the sensitive plate should now be placed under the part and the exposure proceeded with. Preparation and setting of the plate is discussed in a later paragraph.

X-Ray Tube below the Patient.—With the tube above we can only set the tube and plate relative to the part we wish to radiograph, and trust that the view obtained will be that desired. With the tube below we can first view the part on the fluorescent screen, and see the picture which we will afterwards have impressed on the sensitive plate. With the

screen illuminated the tube can be moved, the part manipulated, and the diaphragm adjusted to secure the view which best gives us the desired information.

We may also judge directly whether the tube in use is giving the requisite contrast in shadow to secure a good radiogram. These points adjusted, a sensitive plate is substituted for the screen, and we can with assurance proceed with the exposure. The advantage of a table adapted for this position of the X-ray tube will now be understood, but the absence of a specially constructed table need not always prohibit exposure from below. An ordinary canvas stretcher may be supported at each end, and, with the patient on this, an X-ray tube fixed in an ordinary tube-stand may be placed under and the exposure proceeded with.

An adjustable or iris diaphragm is quite essential to secure the best results, but cannot be conveniently used with a tube above the plate, since there is no opportunity of directly ascertaining the part actually illuminated. With a tube acting from below, the diaphragm is fitted 2 or 3 inches above the tube, and serves to cut off all unnecessary marginal rays, which would otherwise produce cross-shadows and blur the outline of the picture. The diaphragm should be contracted so as to illuminate just as much as is really desired to be seen in the radiogram.

Inclusion of surrounding parts is of no value unless for localisation, and by restricting the area of exposure by the diaphragm much better definition of outline and detail is obtained.

With a large area of exposure, indeed, the image of the marginal parts is commonly so distorted as to be almost useless. This is due to the obliquity of the rays reaching them as explained in an earlier section (see p. 91). As there mentioned, in addition to oblique marginal rays from the target, there are irregular rays emanating from the glass walls of the tube, which further confuse the image, if not cut off.

Where it is necessary to view a large area, it is much better practice to make two separate radiograms of adjoining areas, setting the tube appropriately for each.

IV. The Sensitive Plate.

Ordinary photographic plates may serve for radiography, and are often so used with satisfactory results.

Special plates are, however, manufactured, and give more uniformly good results. These plates are usually modified to give extra density of image, this being secured by coating them with more than one layer of sensitive emulsion. We have for some time regularly used special radiographic plates, which are said to be triple coated, and we find them very satisfactory, and quite worth their additional price. The ordinary sensitive emulsion is quite transradiant to X rays, hence superposition of several layers produces a cumulative effect. If some film could be devised possessing more 'stopping power,' then we might expect more definite pictures.

Recently, we are pleased to note, the Ilford Photographic Company have taken up the manufacture of special radiographic plates. The quality of these is testified by a worker in the *Archives of the Roentgen Ray*, of April, 1908, and we believe this is in accord with general experience.

It must be remembered that radiographic plates are sensitive to ordinary light as well, so that all manipulation of them must be performed in a carefully darkened room, lit only by green or red light, which should preferably be diffused by the use of some fabric or ground glass.

Plates should be stored in a cool, dry place, and, if anywhere near a source of X rays must be stored in a lead-lined box. It is much better, however, to store plates at some distance from the operating-room, with the exception of those that may be required for immediate use.

As sold, the plates are wrapped in opaque paper, and packed in dozens in sealed cardboard boxes. The sizes which it will be found suitable to stock are $4\frac{1}{4}$ inches by $3\frac{1}{4}$ inches, known as 'quarter-plate'; $8\frac{1}{2}$ inches by $6\frac{1}{2}$ inches, known as 'whole-plate', and 12 inches by 10 inches. It is a wise economy to use always the smallest plate that will include the desired view, and such practice will help to justify the use of plates of the best, though more expensive, manufactures. Where possible, the operator should decide in advance what

plates he is likely to require, and before commencing the other work he should get those prepared for use. To do so the required plates are unpacked in the dark-room, preferably without any illumination, and each is enclosed in paper **envelopes opaque to ordinary light.** Usually two envelopes are so employed—the inner one of orange colour, the outer black.

In placing a plate in the first envelope, it is necessary to know on which side of the plate is the sensitive film, and the absence of light may make this seem at first sight difficult. With a very little experience, however, the film side may be detected by touch, being soft and velvety by contrast with the side of bare glass, which is cold and slippery.

Another test suggested is by touching with the tongue, to which the film side is felt sticky; but touch alone is usually sufficient.

The film side should be carefully dusted, then the plate placed in the orange-coloured envelope, with the film towards the plain side of the envelope—that on which an address would be written.

Then this envelope should be placed inside the black envelope, with its flap towards the closed end and its address side towards the same side of the latter. By this arrangement one can always know towards which aspect the film side of the plate is turned.

This it is essential to know, for the plate must always be turned with this **sensitive side towards the X-ray tube.** If turned otherwise, the glass would interfere to some degree with the passage of the rays, and in interpretation of the radiogram confusion would arise in defining right and left sides of the view. This latter difficulty of interpretation from a radiogram alone, where conditions of exposure are not carefully observed, is no imaginary one, as anyone with experience will know; and especially is it so when a radiogram has to be expounded to one anxious but ignorant regarding such matters.

To obviate the difficulty, we find it a good plan to interpose a **metallic object opposite one definite corner** of every radiogram. This may take the form of a small metallic clip

adapted for the purpose, or a suitable piece of metal may be fastened by adhesive material to the face of the envelope. Where a system is adapted of numbering all plates by interposing metallic type in their exposure, the number may be printed always in one defined corner. This numbering may be done by combinations of separate numbers in solid or in stencil type, which are fastened on the face of the envelope by gummed paper just before exposure; and in the record book the exposure is entered under the corresponding number, thus facilitating reference. Instead of metal type, a label may be written on with an ink made of a suspension of a salt of bismuth in gum and spirit. On this may be entered any information desired besides its reference number, but, although the latter plan sounds enticing, we have found the metal type more satisfactory. The mark differentiating the sides of the radiogram may be made of a private nature, so that, as in legal cases, advantage may be retained by the radiographer.

The plate thus prepared is placed in position under or over the part to be radiographed, care being taken that its sensitive side, as indicated by the plain or address side of the envelope, be turned towards the patient, and thus also towards the X-ray tube.

With the tube above and plate below, the superimposed weight of the part must be relied upon to keep the plate steady and in position.

With the tube below and plate above, there is opportunity of exerting some pressure on the plate. Besides keeping it steady, this may serve to bring the plate in closer apposition to the bony or deeper parts of which a view is usually desired, which apposition is desirable so as to avoid distortion as far as possible.

For this purpose we find it good to place on top of the plate the flat board faced with sheet lead, to which we have already referred. The use of compressors in a similar way is discussed in an earlier chapter on 'Accessory Apparatus.'

To avoid another source of distortion, the plate must be held as nearly in a horizontal plane as the contour of the underlying surface will allow.

Exposure completed, the plate should be removed at once

from the operating-room, whether or not it be intended to proceed immediately with its development, since subsequent radiation, even from a distance, might otherwise seriously affect it.

V. Development.

To one acquainted with development of ordinary photographic plates, the after-treatment of exposed X-ray plates need offer no difficulty. In each case the impression made on the sensitive plate by exposure may be said to be 'latent,' since no change is visible in it until acted on by a suitable chemical solution or developer.

This process is simple, if intelligent care be exercised in its direction; but much of the success of a radiogram may, nevertheless, depend upon it. Care and cleanliness are the two chief requisites for its successful execution. Many excellent manuals of photography are published which explain the rationale and details of the process of development, and perusal of one of these will well repay anyone unacquainted with the subject to whom the brief notes here set down may be insufficient as a complete guide. Later on we shall detail the steps of the process, but first consider a few important points.

The **time** occupied by development will depend naturally upon the length of exposure relative to the subject exposed, and also upon the strength of the developer. With proper exposure a plate should be allowed about ten to fifteen minutes to develop. It may be done much more quickly, we allow, with good results, but little is gained by rushing the process, and much may be lost. With over-rapid development much of the finer detail in the picture is inevitably lost. The dangers of prolonged development are fogging by exposure to light, or changes in the film due to prolonged immersion.

Any of the ordinary **developers** may be used, but it is well to follow the instructions which are always published with plates as sold, and which vary slightly for different brands of manufacture.

At one time we evolved a developer on our own account to suit the special qualities of X-ray plates, but we abandoned

that, and have for some time used a developer specially recommended by the Lumière Company.

We have reason to be highly satisfied with the action of this developer, the formula of which is:

DIANOL (DIAMIDOPHENOL) DEVELOPER.

Dianol	5 grammes	or	40 grains.
Anhydrous soda sulphite ...	30 grammes		250 grains.
Water	1,000 c.c.		20 ounces.

It is advisable that solutions of dianol be made up at the time of using, as the developer gradually loses power on keeping.

The sulphite solution may be made up and dianol added as the developer is required for use, but we prefer to keep each constituent in powder form.

Thus, each powder may be made up in packets containing the requisite quantity for 20 ounces of developing solution, the two powders being wrapped in papers of different colour. Then at any time one packet of each may be added to 20 ounces of water, and fresh developer is at once ready for use.

It is recommended to carry development with this developer a little further than usual, as some slight loss of density takes place in the fixing bath; and it is stated that 'for under-exposure the proportion of sulphite of soda may be increased, while for over-exposure, if the amount of dianol be increased, good results may be obtained from grossly over-exposed plates.'

Another formula which is highly recommended, and which may be more readily obtainable, is:

PYRO-SODA DEVELOPER.

Solution A.

Pyrogallic acid	20 gms.	or	1 oz.
Sod. sulphite	60 gms.		3 oz.
Water ...	300 c.c.		15 oz.
Nitric acid	30 minims.		

Solution B.

Sod. carb. ...	75 gms.	or	4 oz.
Sod. sulphite	60 gms.		3 oz.
Water ...	300 c.c.		15 oz.

For development, mix in following proportions at time of use:

Solution A.	... ...	6 c.c.	or	1 drachm.
Solution B.	... ...	6 to 10 c.c.	or	1 to $1\frac{1}{2}$ drachms.
Water	... ...	60 c.c.	or	1 ounce.

'Increase the quantity of B. drop by drop during development if the negative has been under-exposed.'

The following sketch of the steps to be observed in the course of development makes no pretence to be exhaustive, but gives us opportunity of noting in sequence some points worthy of special attention in radiographic work.

The room being carefully **darkened**, unless for the green or red light, take the plate out of its envelopes, and gently remove any possible specks of dust from its surface by means of a soft brush or by blowing. Place the plate, film upwards, in a porcelain or composition dish of appropriate size and shape.

Rapidly **flood the plate** with the prepared developer, taking care that the surface of the film is uniformly wet, and that no air-bells are allowed to remain upon it. The former point is best attained by raising one corner of the dish and pouring the developer from that corner, the latter by removing the air-bells with the finger if necessary.

Keep the fluid moving over the face of the plate by giving to the dish a continuous rocking motion.

Watch the plate carefully for the first minute or two, since an over-exposed plate may flash up very rapidly, and must at once be checked.

If no change appear within the first two minutes, it is safer to **cover the developing-dish** so as to protect the plate from the light, since even the coloured light may affect it if freely exposed for any length of time.

On a correctly exposed plate, after about two minutes' development darker patches should begin to appear, and should gradually and slowly form an image. Meanwhile the rocking motion should be kept up and the progress of development occasionally observed.

When the upper surface appears fairly dark, raise the plate and view its under surface. With an ordinary photographic plate completion of development is commonly judged by viewing the plate held between the observer and the light.

This method may also be employed with radiographic plates, but development of the latter must be carried further than with the former. Development with these must be carried, as it were, through the extra thickness of the film, and the criterion of completion is seeing the black shadows plainly marked on the back of the plate.

If before that time the white parts of the plate begin to assume a uniform dirty greyish tint, it may be implied that a 'chemical fog' is setting in and development must be stopped.

Short of such occurrence **over-development is not readily reached**, and a beginner's timidity will more often lead to the opposite mistake.

Errors in Exposure.—In an **over-exposed** plate changes appear very rapidly after development is commenced.

In such a case pour the developer back into its original container and wash the plate rapidly in running water under the tap.

Then dilute the developer with about an equal quantity of water and resume development.

If over-exposure be suspected, then it is well to commence with a weak solution of developer, and have some stronger solution at hand to add if development prove slow.

If **under-exposed**, the plate shews the changes due to development correspondingly slowly.

It is not well to attempt acceleration by strengthening the developer; additional time for development is the obvious and safest remedy, but a satisfactory result need never be looked for with a plate which is under-exposed to any extent.

Probably the best possible result will be obtained by diluting the developer, covering the dish, and allowing development to proceed for a long time. This method, at least, allows the operator to leave development to proceed in safety while he attends to something else. When the dark parts show quite black at the back of the plate, it is needless to prolong the process further.

Various modifications of, and additions to, developers are suggested to compensate for errors in exposure.

Thus, for over-exposure a less proportion of alkali may be used, and for under-exposure a greater proportion. Where

development is prolonged, the addition of bromide of potassium is recommended to obviate the chemical fogging of the plate liable to be produced by the alkali.

But all these measures are very partial in their effect or utility, and we do not recommend the X-ray worker to dabble with them.

No after-treatment will fully compensate for errors in exposure. We therefore advise that all possible attention should be paid to the latter factor, and that the development be cautious but straightforward, as described.

An over-exposed plate will shew absence of contrast between its darker and lighter parts, being termed 'flat,' while an under-exposed plate will rather exaggerate contrast, but will lack detail or depth, being termed 'thin' in quality.

Fixing.—Development being completed as described, **rinse the plate** to rid it of all developer, then **immerse** it in the following fixing-bath :

Sod. hyposulphite (known as 'hypo') ...	150 parts	or	2 ounces.
Water	1,000 parts		14 ounces.

To which may be added—

Sat. sol. of sod. bisulphite ... ... 10 parts or $1\frac{1}{2}$ drachms.

This bath may be made stronger if desired, and then acts more rapidly, but has a tendency to soften the film and cause frilling.

The plate should be kept in this fixing-bath till all the unaltered silver bromide is seen to be removed from the film. This is seen in the disappearance of the last trace of the opaque whiteness of the original film, and is best judged by holding the plate in such a position that the light of the lamp is reflected from it, preferably with something black behind it. In this position the plate should appear uniformly black.

It is better to leave the plate in the fixing solution for a few minutes after the process is thought to be ended, so as to insure its thorough completion.

It is a good plan, if a number of plates are being 'put through,' to have two dishes of hypo solution, reserving the second dish for a final immersion of each plate after it appears fixed in the first.

In very **warm weather** or in **hot climates** it is advisable to add to the above fixing solution **25 grains of alum**, dissolved in hot water and filtered ; and, further, after washing the fixed negative, to immerse it for five to ten minutes in a bath of alum as under :

Alum	60 parts	or	1 ounce.
Water	1,000 parts		16 ounces.

This is to prevent frilling of the film, which may follow undue softening, but we have never found the process necessary in our work in London.

Washing.—After being fixed, the plate must be thoroughly washed for an hour or more in running water. If running water be not available, but only frequent changes in a large dish, then longer time must be allowed—up to two hours or more. Prolonged washing can do little harm, and washing must be thorough to insure preservation of the plate. If the hypo be not thoroughly removed, it will later crystallize on the plate, and spoil it for further use. Preparations are sold under the name of hypo eliminators, in a bath of which the plate must be immersed after fixing and a brief washing, and after which a further washing for a short time only is required. We have no experience in the use of these.

Drying may be done in any place free from dust and moisture, but heat must not be employed. Plates may be set on edge, and supported at an angle against a vertical support, preferably with the film side downwards, to save it from dust; or they may be placed in a suitable rack, which supports them upright, with one angle at the lowest point.

If time presses, a plate may, after thorough washing and short time of draining, be immersed in a bath of alcohol, after which it will dry rapidly. Besides the expense of this, there is a danger of unequal drying and contortion of the film ; but in ordinary work there is no necessity for it, as plates can be examined quite conveniently while wet, and then allowed to dry naturally.

We are in the habit of examining each plate, and making our report upon it after it is but partially washed. The washing is then resumed and continued as required.

Intensification of thin plates, or **reduction** of over-dense

plates, is not to be recommended for X-ray work. By these processes astonishing results may be obtained by professional photographers when employed in improving or 'faking' plates, but this is quite outside the work of a medical radiographer, and should not be attempted. If a plate be not satisfactory, then let the exposure be repeated on a fresh plate.

'Retouching' is, of course, in no case permissible, for though a photographer may gain credit for 'improving on nature,' a radiographer could only so merit discredit.

Storing Radiograms.—If a plate has not already had a number printed on it during exposure, it should, for the sake of reference, be numbered before being stored. This may be done by affixing a written label to it, or by writing with ink on the margin or other blank part of the film.

To avoid scratching of the film, each plate may be placed in a soft paper envelope, on which is written the number of the plate and any desired particulars, the age of the subject being a most important particular to have attached to each plate.

Plates may be stored in batches in the boxes in which they were originally contained, or in the largest-sized boxes; and a rack, suitably divided, may be designed to hold the more recent exposures, so that they are handy for reference.

A record book should be kept of all work done, and in this may be entered such details of cases, notes of process, copy of report, and remarks as may be thought fit.

If any variation of apparatus or exposure be tried, a note of this should also be made; but when an operator comes to make all exposures on a standard basis, it seems unnecessary to repeat the data for every exposure made.

We use a very simple form of record book in our regular hospital work, in which entries are made under the following headings:

Date.	Patient's Name.	Age.	Sent by.	No. of Plate.	Part affected.	Lesion.	Query.	Treatment.	Result and Remarks.

Prints.—It should be remembered that the plate, or so-called 'negative,' is always the most satisfactory and most reliable picture for report or reference. Some of the detail and definition is inevitably lost in printing, and the entailed

reversal of sides of the picture is often confusing. But duplicates of the radiogram may be required, or the record may be desired in a more portable and convenient form, and for these or similar reasons prints are made.

Ordinary **silver printing-out papers** make very suitable prints where sunlight is available. The paper clamped behind the plate in a printing-frame is exposed to daylight until it becomes of a colour a little darker than is finally desired. Printing should not, as a rule, be done in direct sunlight, but rather by diffused light. The former tends to reduce the contrasts of the picture, whilst printing in weak light tends to increase them; and all our efforts are usually directed to secure the latter condition in a radiogram.

After being printed, the paper is submitted to a suitable toning process, and is then fixed. The details of these processes differ somewhat for different classes of paper, and with each packet sold are enclosed printed instructions as recommended by the makers for that special paper. These should be followed, and are usually explicit enough to render superfluous any further remarks here.

Bromide paper is especially suitable for radiographic work, since it gives strong contrasts, and can be printed at any time of day or year by exposure to gas or electric light. Unlike the silver papers, no immediate change can be noted on this paper after exposure, but, like a sensitive plate, it requires development to make the impression visible. Thus, there is no direct means of regulating the duration of exposure, and this is a difficulty which can only be overcome by experience in working.

Correct duration of exposure will depend upon three factors—intensity of light, distance of paper from the light, and character of the negative.

The first can be made standard by always employing the same light for printing—say, a 16 candle-power electric lamp or a certain number of gas-burner. The distance can also be made standard, or at least in fixed ratio, the exposure required varying as the square of the distance. For small negatives such as quarter-plate size a distance of 1 foot is convenient, at which distance from a 16 candle-power lamp

an exposure of about ten seconds should be sufficient. Larger negatives must be kept farther away, or must be kept moving from side to side and up and down during the exposure, in order to secure even illumination.

We recommend printing at a greater distance from the light, since this tends to increase the contrasts, which result, as already stated, is usually desirable. The third factor—character of the negative—is one constantly varying in different negatives, but should vary less as the worker is more experienced in exposure and development of plates.

The density or opacity may be judged by examining the plate held between the eye and a distant light, a sky of white clouds forming a convenient source of diffused light for the purpose. A denser negative, of course, demands longer exposure in printing from it.

Only by trial, however, can a worker hope to get an intelligent idea of this printing process, and if he cannot afford the time to experiment on it, then he had better entrust his printing to a practised hand.

Various developers may be used, but, as with silver prints, we advise that the instructions enclosed with the special brand of paper used should be followed, though doubtless any developer will be more or less suitable for all similar papers. Pyro developers are not suitable, on account of coloration produced in the paper. A suitable formula, somewhat similar to that recommended for plates, is :

Dianol	5 grammes	or	45 grains.
Anhydrous soda sulphite ...	20 grammes		170 grains.
Ten per cent. sol. pot. bromide	2 to 5 c.c.		20 to 50 minims.
Water	1,000 c.c.		20 ounces.

This developer should be freshly made for each batch of prints, or the soda solution may be made in bulk, and the dianol added as required at the time of use.

After development the prints should be well rinsed, and then fixed for five or six minutes in the same hypo solution as is used for plates, or in a special bath as under :

Hyposulphite of soda ...	200 parts	or	$2\frac{3}{4}$ ounces.
Sat. sol. soda bisulphite ...	10 parts		$1\frac{1}{4}$ drachms.
Alum	2 parts		14 grains.
Water	1,000 parts		14 ounces.

'To preserve the purity of the whites, exposure should in all cases be sufficient to allow development to be completed, and full density attained, in from thirty to forty seconds. Care should be taken to handle the bromide papers as little as possible, as pressure or friction caused by careless handling will give rise to black markings during development. These may, however, generally be removed by gentle application of a tuft of cotton-wool moistened in spirit.

'To prevent uneven development of large prints, it is as well to soak the paper in water before development, care being taken to remove all air-bells.'

It will be seen that this bromide process is specially suitable for the usual needs of a radiographer, although in itself more difficult to carry out successfully. The stronger contrast obtained in the picture is desirable, while the shorter time involved, and the possibility of making a print by artificial light, render the process at times very convenient.

Employing this process, we have admitted a patient, completed a negative (drying it by spirit after a brief washing), and presented him with a finished print all within one hour.

The print while wet may be pressed by a rubber roller or 'squeegee' with its face against a sheet of glass, to which it will adhere. In this position it may be safely handled for temporary examination, and it may, if desired, be fastened at its edges and allowed to dry gradually on this as a permanent mount.

After washing, prints should be allowed to dry by laying them face upwards on a clean cloth or blotting-paper in a place as free from dust as possible, or they may be suspended from a line by means of clean wooden clips gripping the print at one corner.

CHAPTER VI

INTERPRETATION OF ORDINARY AND STEREOSCOPIC RADIOGRAMS

As already mentioned, the report on a radiogram should always, where possible, be made from the negative. This is examined by transmitted light, the plate being placed between the eye and the source of light. To do this conveniently some form of lantern is advisable. A simple desk, with central area transparent like a photographer's retouching desk, may be employed where daylight is available. But daylight is very variable; thus it is better to work with artificial light, which will always be available, and which, being of constant intensity, will allow comparison of negatives.

A lantern, then, is required with one flat and transparent face on which the negative may be placed, while the other sides of the lantern are opaque, the inside reflecting the light obtained from a suitable source in the middle of the lantern.

Fig. 57 shews such a lantern. The one employed by us serves also for stereoscopic views, as described later. The transparent face is of opal glass, which diffuses the light reaching the negative; the other two sides are lined with opal plates with opaque backing, which reflect the light from an electric lamp supported in the centre of the lantern. On the transparent face are a series of frames, so fitted as to accommodate any size of plate ordinarily used. This is a most convenient piece of apparatus, but a much less expensive form can easily be made or adapted. Thus an ordinary dark-room lamp, with a sheet of ground glass or opal substituted for the ruby pane, will serve; or a tin lantern after the same design, and painted white inside, may readily be made.

Where electricity is available it certainly forms the best mode of illumination. Care must be taken not to leave a negative too long in contact with the window of such a lantern, especially if the negative be wet, or the heat may soften the film, with disastrous results.

To examine a negative, place it with the film side outwards on such a lantern. If the opaque frame does not fit closely round the edges of the plate, lay strips of black paper or similar opaque material along these, so as to cut off all direct light from the eyes. Darkening the room will make the illumination of the negative much more efficient.

Densities of Shadow.—The first point to be remembered in reading such a radiogram is that, as the name 'negative'

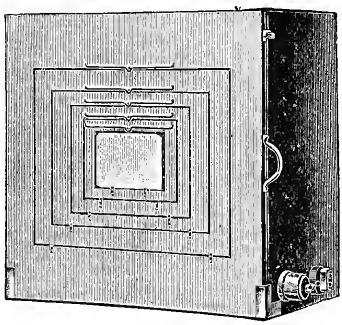


Fig. 57.

implies, the **plate** shows in density of shadow the reverse of the relative densities of the part exposed. Where dense tissue, such as adult bone, is interposed, much of the radiation is prevented from reaching the sensitive plate; hence little chemical alteration takes place in the corresponding parts of the plate, and the final result is a light transparent image of that tissue. Where, on the other hand, transradiant tissue, such as muscle, or, more markedly, air-filled organs, are interposed, much of the radiation reaches the sensitive plate, there is marked chemical alteration, and the result is a dense opaque image of that tissue.

Thus, clear transparent parts of the negative correspond to dense tissue, and dense opaque shadows to more transradiant

parts. All grades of density, of course, appear and must be interpreted as meaning either normal differentiation or abnormal change. To diagnose the latter, an intimate knowledge of the former is essential. Even where such knowledge has been acquired by experience it is advisable, whenever there is any reason whatever for uncertainty, that a radiogram of the corresponding part of the patient on the other side be made under exactly similar conditions for comparison. The advantage of this will soon be seen in practical work, and may be understood from its bearing on several points considered later in the section on diagnosis.

In a **print** everything is again reversed, so that dark shadows correspond to denser structures, and lighter parts to more transradiant tissue; hence such records are sometimes termed 'positives.' To the inexperienced, prints are thus easier to read than plates, though to the experienced radiographer they are of secondary value.

Right and Left Side.—From the radiogram itself, without any information as to the conditions of exposure, it is always difficult, and may be impossible, to tell which side corresponds to the **right and left side** respectively of the part radiographed, unless there is some indicating mark on the plate.

But if we are told on what aspect of the patient the **plate** was situated during exposure, we are able to settle the point.

In such case hold the plate with its film side towards you, and imagine your eye to be in the position of the X-ray tube during exposure. Then the right and left sides of the radiogram will correspond to the sides of the patient as he would appear from that position.

Thus, if the patient had his back to the tube and the plate in front of him, you must suppose yourself looking at his back, and the side of the radiogram to your right hand will correspond to the right side of the patient. On the contrary, if the patient had his face turned towards the tube and the plate set behind him, you must suppose yourself face to face with him, and the side of the radiogram towards your right hand will correspond to the patient's left.

On a **print** this relation is reversed, since the plate in printing is turned with its film side towards the paper, and

away from the source of light. To realise the relations of a print is thus very confusing. A little consideration will, of course, define the relations of any radiogram if we know the conditions of its exposure, but it is better to obviate the necessity by placing some indication on the plate during or after exposure.

Dimensions.—The dimensions of shadows as seen in a radiogram are not a true index, either absolutely or relatively, of the dimensions of the objects casting those shadows.

This point is discussed in other sections of the book. As there explained, all objects are magnified in a radiogram according to their distance from the sensitive plate, objects situated nearer to the plate being magnified to a less degree than those at a greater distance from it. This might be expressed by saying that a radiogram resembles a drawing in perspective, the eye being in the position of the X-ray tube.

By bearing in mind this fact, and applying his knowledge of anatomical dimensions, an observer may calculate from a radiogram the relative position of the parts depicted. Without such knowledge of actual dimensions, some idea may be gained of the relative distances of objects from the plate by noting the clearness of the outline of their images. An object near to the plate will cast a more clearly defined shadow as compared with that cast by a more distant object.

But this is a very indefinite indication, and would seldom, if ever, be relied upon for any practical purpose.

Thus it will be seen that a single radiogram gives a clear idea of the relative position of objects only in relation to the plane in which the plate was placed during exposure.

To obtain a visual conception of the true relative position of objects depicted by radiography it is necessary to take two views, which may be combined stereoscopically.

Stereoscopic Views.—We may remind readers that our conceptions of solidity, or of the relative position of objects in space, are obtained by the superposition of two visual images, one of which is perceived by either eye.

The principle of stereoscopic photography is to take two views of the same object from positions corresponding respectively to the right and left eye of an observer. By suitable

means the observer is caused to receive simultaneous impressions of these two views, one by either eye, so that the impressions may be superposed in his sensorium. By this means the combined views convey a sense of solidity and distance quite impossible to obtain from a single view.

In radiography the principle applies in the same way as in ordinary photography. Two plates are successively exposed in exactly the same position, but between the two exposures the X-ray tube is moved through a distance equivalent to that between the two eyes of an adult person, which distance may be taken as 3 inches.

Various arrangements are in use to make these adjustments possible and convenient. Probably the simplest plan is to have the patient on a transparent couch, as described earlier, and to place the plates directly over the part to be radiographed, while the tube is moved under the couch as required. Having the patient in position, apply the fluorescent screen, and by its aid set the tube exactly under the centre of the part to be radiographed; then for the first exposure move the tube into a position $1\frac{1}{2}$ inches on one side of this central position. With the X-ray couch described, this is conveniently measured by the scale on the horizontal rod attached to the tube-box.

Then take the first plate and shake it so that it fits closely into one corner of its envelopes. Lay it in position over the part with one edge parallel to the line in which the tube has been moved, and mark on the skin the position of two adjoining sides of the plate. If the part exposed be too small to permit of such marking, then the plate may be supported on blocks of the same height as the part. On these, placed alongside the part, the two marks may then be made.

Make an exposure and remove this plate. Fit the second plate similarly into one corner of its envelopes, and place it with two edges fitted to the lines marked on the skin or adjoining support. Now (or before setting the plate) move the tube to a position $1\frac{1}{2}$ inches in a direct line on the opposite side of its initial central position—that is, 3 inches from its position during the first exposure—and make the second exposure.

In certain cases such simplicity of procedure may be impossible, and many suggestions have been made to facilitate the accurate adjustment necessary.

In addition to the steps described, a metal cross-wire may be fastened on the skin parallel to the path of the tube, and in such a position that it will be overlapped a little by one corner of each plate in turn. The image of this on each plate will facilitate the after-setting of the plates for inspection.

Where large-sized plates are used, we support them on the upper part of the travelling-frame of the table described, bringing that close down on the part to be exposed. A special support or a changing-box may be attached to such a frame fixed above the patient, and is frequently employed for stereoscopic work. Whatever arrangement be adopted, the setting of the X-ray tube under the patient renders the process much more simple and exact than with the older setting of the tube above.

Where the tube must be set above the patient, some form of changing-box is necessary which may retain its position under the patient while the plates are changed. This usually consists of a frame with top permeable by the rays, and strong enough to support the weight of the patient. Into this the plates fit in succession, and along one side there is frequently a strip of metal which overlaps each plate a little, and thus marks a line by which the plates may afterwards be set in alignment. The tube-stand should be made with a horizontal arm, on which is marked a scale, and along which the tube may be moved through the specified distance.

In order to view stereoscopic radiograms, it is usual for some suitable form of stereoscope to be used, though it is possible to combine two such views into one, giving a sense of relief by the unaided vision. This requires some practice to accomplish satisfactorily, but it is well worth knowing and learning to do, for a stereoscope is not always at hand. The two radiograms should be set side by side, and the observer should set himself so as to have one opposite each eye. If he hold up a finger between his eyes and the radiograms held near to him, one to each side of his line of mid-vision, and look at the finger, the visual axes will cross, and he will see two views of each radiogram. By accommodative effort he may cause the two central

images to be superposed, and, ignoring the two outside images, he will see one view shewing the part radiographed in relief.

For routine work, however, some form of stereoscope will be used. That known by the name of Wheatstone serves well. As shewn in Fig. 58, this consists of two upright frames to support the views at either end of a short baseboard, in the middle of which are two plane mirrors, arranged on a vertical support at the same height as the frames, and fixed with their backs forming an angle of 90°.

With a pair of radiograms in position, the observer places himself so that the space between his eyes is divided equally by the vertical edge where the mirrors meet. With his face

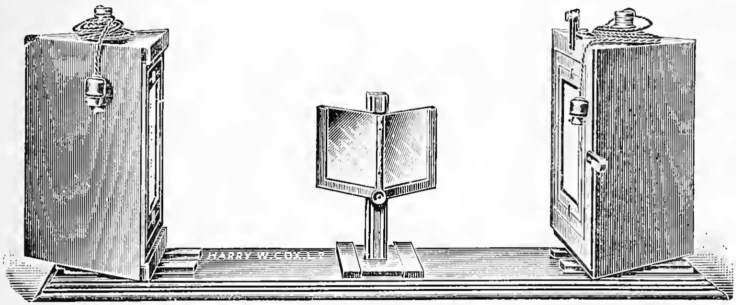


FIG. 58.

close to this edge, each eye will see the reflection in the mirror before it, and the two images thus seen will be merged into one perception of an image in relief.

Prints are easily viewed in this manner, and may be adjusted on the supporting-frames by clips or pins.

The arrangement is figured as adapted for plates, the end-pieces permitting illumination as described relative to Fig. 57. This form for viewing plates is of more general use. Prints certainly shew up better than plates, so far as the stereoscope is concerned, but prints never shew the same detail or precision as the plates from which they are made.

The additional time necessary to make prints is a further drawback to their use in routine work, it being possible to view plates and make a diagnosis from them before they are dry if necessary. The central support carrying the mirrors is

usually made with its base fitting into slides fastened on the baseboard transversely; thus the alignment of the mirrors with the radiograms may be altered as desired. The frames or lanterns at either end are fitted so that they may be moved nearer or further from the mirrors, and in the more elaborate instruments there is further arrangement made for orienting the radiogram, so as to secure more accurate coincidence of the images. This mechanism is largely superfluous, though convenient, since it is found that the eyes by effort of accommodation can rectify considerable lack of alignment or coincidence. This will be readily understood when it is remembered that, as described earlier, two such views may be combined by the eyes unaided by any apparatus.

To obtain the correct relief of a part, the separate images must be received each by the appropriate eye, otherwise the relief will be reversed. By trial, in most cases, it will readily be seen whether the relief be correct; but for such purposes as location of a foreign body anatomical knowledge may not furnish such a guide, so it is important to understand how the radiograms should be set.

The operator must again imagine himself set with his eye in the position of the X-ray tube, and in this case it will be his right and left eye alternately, the tube travelling in a line at right angles to his visual axis. To prevent confusion, where the patient is lying down, the operator must always suppose his own head and feet to be in corresponding positions to those of the patient. Following this convention, we name each radiogram by the side—right or left—of the operator towards which the tube was situated during its exposure. By thus naming them with respect to the observer the same rule will apply to all radiograms, whether placed on the front or back of the patient.

If the radiograms be viewed direct, without intervention of mirrors, they should be placed with the right-hand view to the observer's right. If they be viewed in the reflecting stereoscope the positions must be reversed, since the reflection is the reverse of the original on the plate. With prints the rule is reversed in either case.

A simple method of securing a view of radiograms in an

ordinary hand stereoscope has been suggested to us, and offers great promise, though we have been prevented so far from testing it practically.

The plan is to make a reduction of each radiogram on a sensitive plate or a bromide paper of size suitable for a hand stereoscope. This could be done while the original radiogram was still wet, and the reductions could be viewed immediately after developing, fixing and washing.

The use of the hand stereoscope would, of course, dispense with all special apparatus or illumination.

CHAPTER VII

LOCALISATION OF FOREIGN BODIES

Most foreign bodies which find their way into the tissues or organs are more dense than the surrounding tissues. Thus they may be detected by the dense shadow cast on an X-ray screen or a radiographic plate.

All metals and most varieties of glass (potash glass less than lead glass) cast an unmistakable shadow, though such substances as wood, leather, cloth, or paper cannot usually be so demonstrated.

To ascertain the exact position of a foreign body, and note it for the guidance of a surgeon in its removal, various methods may be employed.

These may be classified thus:

I. **By Screen Examination.**

(*a*) If the part to be examined will permit, it may be viewed by the screen in two positions at right angles, and a cross marked on the skin in each position in the line of the shadow. Then, where the perpendiculars from these points so marked may be supposed to intersect, the object will be found.

For this purpose the X-ray tube should be centred carefully, the diaphragm contracted, and the tube moved till the shadow of the object occupies exactly the centre of the luminous area.

The marks are made on the skin by a pen with ink, or by a 'skin pencil,' either being guided by its shadow on the screen.

(*b*) **Shenton's localiser** is a simple apparatus whereby the depth of an object from the screen may be readily and

accurately measured. This, combined with a cross-mark on the skin denoting the horizontal position of the object, will serve to locate a foreign body in any part. It is described fully below, and is the method recommended by us for everyday work, unless where very exact measurement may be required, as in the orbit, for which part a special method is described.

II. **Radiograms.**

(*a*) **Taken in the ordinary way,** radiograms are quite unreliable for localisation, and tend often to serious error.

(*b*) **Stereoscopic views** may be taken, and serve well.

Surgeons prefer this method, as it shows the correct anatomical relations of the body in a way easily comprehended. For description of the method of making stereoscopic radiograms, see Chapter VI., at page 125.

(*c*) **Mackenzie Davidson's localising apparatus,** with cross-thread localiser, is a classical method, and from the exactitude of its principle well deserves to be taken, as it is, as the model for most other exact methods. Though ingenious and exact, it is not practicable for ordinary everyday work, being complicated, and involving much apparatus, time, and expense. We include, however, a description of the method, partly because of its educative value, but mainly in relation to the special adaptation described for bodies in the orbit. For eye-work the method is especially serviceable, since less complex methods fail in this special situation.

(*d*) **Dawson Turner's mathematical formula** is simple enough of itself, but, though a nice exercise, it is not practical enough for everyday use.

Shenton's Localiser.—Let a screen be fixed in position some distance above an X-ray tube, while the latter is moved in a plane parallel to the screen; and let a small opaque object be interposed so as to cast a shadow on the screen. If that object be close against the screen, it will be readily understood that the shadow cast will not perceptibly change position on the screen as the tube is moved. But if the object be some distance below the screen, the shadow will be seen to change

position as the tube is moved; and as the object recedes from the screen towards the tube, the path traced by its shadow will gradually lengthen for the same travel of the tube.

A glance at the accompanying diagrams (Fig. 59) will explain this more clearly than words.

If the part examined have bone in it, then by noting the relative paths of the shadow of the bone and of the object, we may tell directly whether the object is on the side of the bone proximal or distal to the screen. This may be valuable knowledge, but in most cases is too indefinite to guide exploratory operation, and further information is required by the surgeon. Fig. 60 illustrates the conditions referred to.

Shenton's localiser takes advantage of the fact illustrated above, and by a simple mechanism reduces it to exact terms.

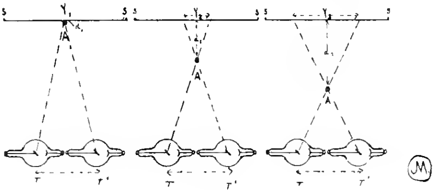


Fig. 59.

S S, Fluorescent screen; A, small opaque object; d_1 d_2 d_3, distances of A from the screen; T T^1, positions of X-ray tube at either end of travel parallel to S S; X, fixed length of travel of tube; Y_1 Y_2 Y_3, path of shadow of A at distances d_1 d_2 d_3 from screen.

It consists of a simple piece of apparatus, whereby an opaque test object may be temporarily fixed at any distance from a screen, so as to be interposed between that and an X-ray tube, which illuminates the screen from below.

It is shewn in accompanying figure fixed to the frame of a fluorescent screen at A (see Fig. 61).

In the fixed part the rod (B) can be moved vertically, carrying with it the horizontal arm (C), which is tipped by a pointed mass of lead (D). The rod (B) is gripped by the sleeve (E) somewhat tightly, so as to prevent it slipping down by its own weight, and may be further fixed by the screw (F).

The rod (C) can likewise be moved in the sleeve (G).

Along B is marked a scale of inches or centimetres, from which the vertical distance of D from the screen may be read, or this distance may be measured directly.

In use, the fluorescent screen should be placed in a horizontal position, in contact with the upper surface of the part to be examined. A shadow of the foreign body being seen, the X-ray tube must be adjusted so that the shadow occupies the centre of the area illuminated through a contracted diaphragm. The position is marked on the skin, as described

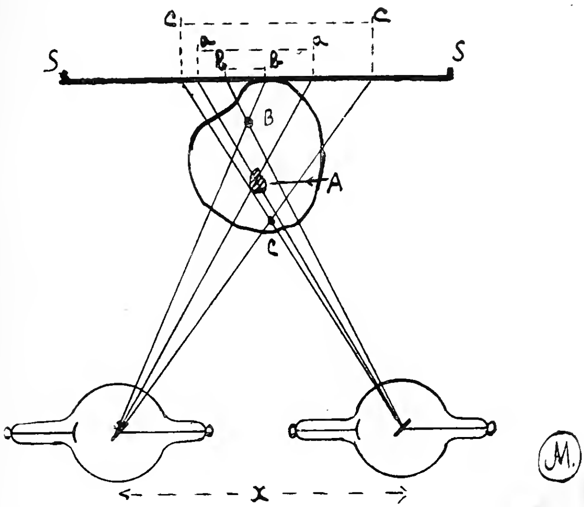


Fig. 60.

S S, Screen ; A, bone of limb ; B C, foreign bodies in limb ; X, travel of X-ray tube ; a a, path of shadow of bone ; b b, path of shadow of B ; c c, path of shadow of C.

in an earlier method, by a cross, and the localiser is then brought into use. Set the horizontal arm (C) and the test object (D) fairly near the screen, and move the tube slowly in any horizontal direction. If the foreign body sought be at some distance from the screen, the increased range of movement of its shadow, as compared with that of the test object, will readily be noted. If the two objects be more nearly in the same horizontal plane, the difference will naturally be less. Adjust the height of D until, by repeated trial, a

position is reached in which its shadow has a travel exactly equal to that of the object sought; the two objects will now be at equal distances from the screen.

If the distance of D from the screen be then ascertained by reading the scale on B or by actual measurement, the

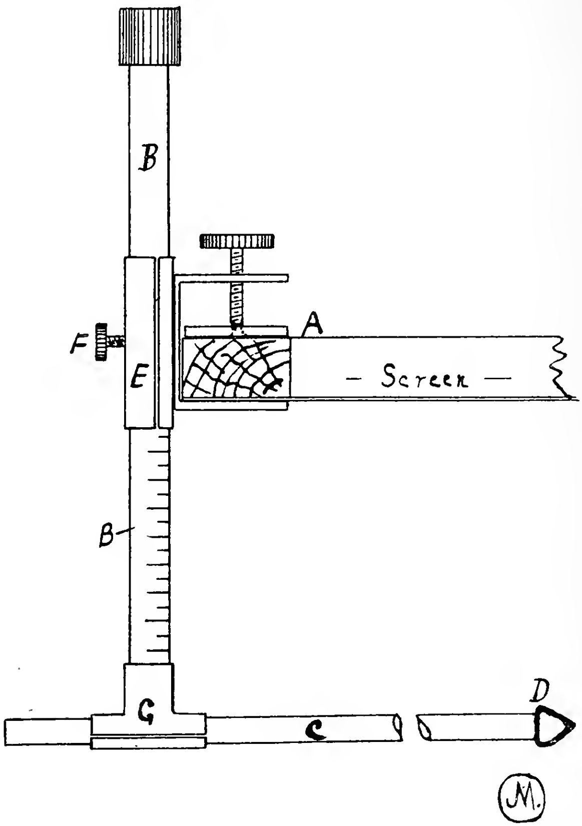


Fig. 61.

surgeon may be told that 'vertically under the point marked on the skin, and at that measured depth from the surface, he will find the object sought.'

This is exactly the information the surgeon wants for guidance in operation, and the radiographer may leave to him its interpretation into anatomical relations.

With the table described earlier on page 87 (Fig. 49) we have been accustomed to support the screen on the upper frame of the travelling-carriage, and to clamp the localiser on one end of the screen.

With this arrangement, however, it is only possible to give the tube a transverse movement relative to the screen, whilst in most cases the two shadows to be observed have their connecting axis also transverse. It will be found that the relative paths of the shadows are much more easily judged when the movement is at right angles to their connecting axis;

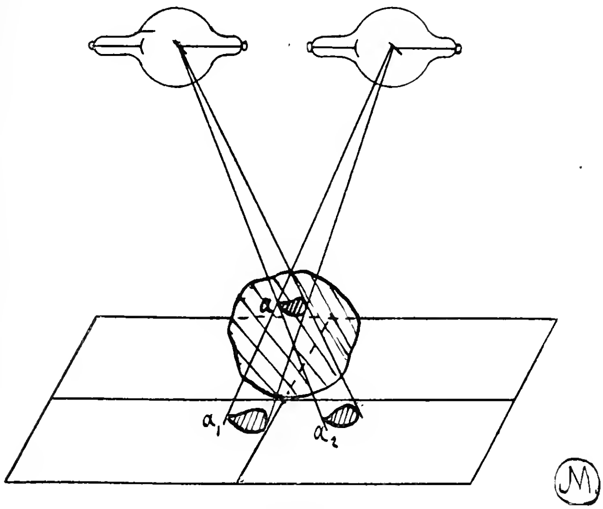


Fig. 62.

thus it will be preferable to support the screen independent of the carriage, and allow movement of the tube in any direction found most suitable.

A little practice with this apparatus on a piece of lead embedded in some transparent mass, such as a piece of wood or a loaf of bread, will demonstrate its usefulness and precision.

For any purpose other than locating a foreign body in the orbit there is, indeed, no necessity whatever for any more elaborate apparatus.

Mackenzie Davidson's Localising Apparatus.—With an

X-ray tube and screen fixed in position relative to an interposed object, it is evident that a straight line passing from the focal point of the tube to any point of the shadow cast on the screen must pass through the corresponding point of the object, as shewn in one plane in Fig. 62.

Then, as shewn, if the tube be moved into another position, while the object remains stationary, the same will hold true, and another line be obtained, which must pass through the same point of the object. Thus the intersection of those two lines will determine the position of the point in question.

This, applied to foreign bodies in the tissues, is the principle of the localising method first described by Mackenzie Davidson.

With the tube and sensitive plate set in definite known relation to each other, two radiograms are made of the part enclosing the foreign body, and between the two exposures the tube is moved through a definite measured path parallel to the plate. Then the relative positions of tube and plate are reproduced, and rays from the focal point of the tube in its two positions are represented by threads passing to two corresponding points of the shadows formed of the foreign body. By the crossing of these threads is indicated the position in space of that point of the object relative to the plane of the plate during exposure.

To make possible this reproduction of the relative positions, and to translate the ascertained position in space into terms which may direct a surgeon, several points must be carefully attended to, and several more or less complicated arrangements have been devised.

Figs. 63 and 64 shew two similar arrangements of a simple type for regulating the exposures. Special tables are also made; some with a transradiant section and plate-changing box below, while the tube is set above the patient, others allowing exposure with the tube below, but the principle is the same in all. On the plate-supports shewn in annexed figures, on the transparent part of the table, or (in the simplest arrangement) on the plate envelopes, are two cross-wires at right angles, and under these the plate must be placed so as to have their position imprinted on it in exposure.

With the patient in position these wires leave on his skin an impress which must be made permanent, either by previously inking the wires or by later tracing with an indelible pencil.

The X-ray tube must first be set with the antikathode vertically above the crossing of the wires, at a distance of about 15 inches, or 37 centimetres. The actual height may vary without affecting the result; but, when fixed, the distance between the antikathode and the sensitive plate must be carefully measured and noted. This centering of the tube may be assisted by use of a plumb-line, or by the crescent-

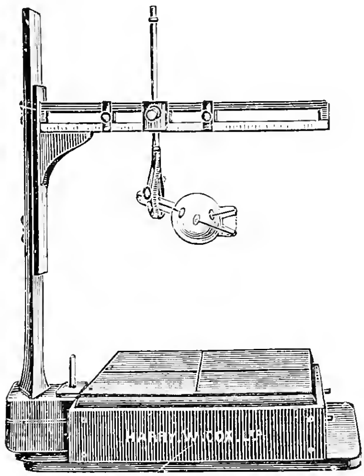


Fig. 63.

piece shewn on the upright in Fig. 65, which shews the latest form of the localiser. In that form the vertical scale marked on the upright furnishes a convenient and exact method of measuring and reproducing the distance of the antikathode from the sensitive plate. For this purpose the upright is detachable at its base. It is first set up on the plate or plate-box, and the crescent-piece (without the T-piece shewn in figure), is set to encircle the tube, so that its two ends are in the same horizontal plane as the antikathode.

The height may then be read on the scale and noted, but the upright should be removed without altering the position of the

crescent, so that when its base is set on the localiser, as shewn in the figure, the position of the antikathode is reproduced directly.

The approximate position of the foreign body having been observed by a previous screening, the patient is now placed in position, so that the object will lie somewhere near the centre of the area crossed by the wires. Those may be covered meanwhile by a board, until the patient is suitably placed and comfortably settled, then the board removed. Place a coin or other mark, such as an indicating number, above the

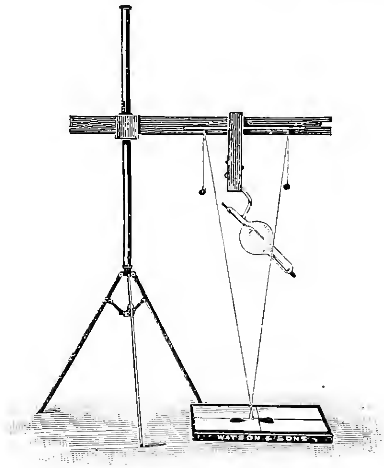


Fig. 64.

plate in one quadrant of the cross-wires, and mark the same quadrant on the patient's skin, so as to prevent after-confusion in interpreting the record.

The patient thus set, move the X-ray tube through a distance of 3 centimetres horizontally, as provided for on the horizontal arm of its holder. This arm, as shewn in Figs. 63 and 64, must be set parallel to one of the cross-wires, so that the travel of the tube will be in the same vertical plane. The actual extent (within limits) of this movement, like the height, does not affect the final result, provided that the distance be measured and noted, so that it can be exactly reproduced later. If the sensitive plate be not in position, the tube may now be

tried, and then the plate placed in position under the cross-wires. The plate being in position, make a first exposure.

Then move the tube horizontally to a point 3 centimetres (or other distance as noted) on the other side of its initial central position, and make a second exposure. This second exposure may be made on the same plate as the first, but is preferably made on a fresh plate. One plate may serve if the part exposed be very thin, and the foreign body very dense, or if a plate-changing box be not provided, and changing of the plate be therefore liable to disturb the setting of the part.

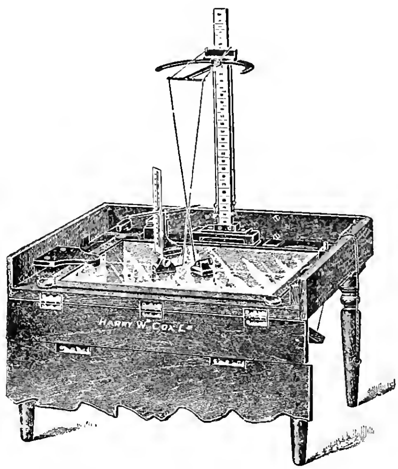


Fig. 65.

Before removing the patient see that the cross-wires are well marked on his skin, along with an indication of the quadrant which is marked on the plate.

Then develop the plates, and, when they are dry, proceed with the next part of the localisation. This may be done with less loss of time if drying of the plates be hastened, after thorough rinsing, by a bath of spirit or 1 in 20 formalin solution.

Fig. 65 shews the latest form of the **cross-thread localiser** now employed to interpret the recorded data.

On the horizontal glass surface of the table are marked two lines crossing at right angles, which correspond to the cross-

wires imprinted on the plates exposed. This surface is illuminated from below by a plane mirror, the angle of which is adjustable. The upright already referred to, with the addition of a T-piece marked by a notch at 3 centimetres on each side of its centre (shewn fastened to the crescent-piece), reproduces the positions of the X-ray tube.

If one plate has been exposed, lay that, film upwards, on the glass surface, and set it so that the image of the cross-wires corresponds exactly to the lines on the glass. If two plates have been exposed, these may be superposed on the localiser so that the images of the cross-wires coincide with each other and with the lines on the glass, but it will usually be preferable to trace each in succession on a sheet of celluloid. That should be similarly set on each plate while the tracing is made, and then it should be placed in position on the localiser. A single plate may be similarly traced, if illumination of the localiser render its record indefinite. With plate or celluloid in position, arrange the mirror underneath so as to throw a good light upwards.

Now pass a thread, as shewn in the figure, over the T-piece at each point representing the antikathode, and lead one thread to each of two small pointers attached to weights with flat bases which rest on the surface of the plate or celluloid. (To the other end of each thread is attached a small weight, which keeps it taut.) Place the flat weights so that the threads cross, as shewn, and place the pointer of each to a corresponding point of each shadow of the foreign object.

These threads now represent rays passing from the antikathode of the tube in its two positions; and, were the patient in position, each of these would pass through the same point of the foreign body. Thus the point of crossing of the threads (which should just touch each other) indicates the position occupied in the exposure by that point of the foreign body which corresponds to the points indicated in the shadows.

The perpendicular distance of the crossing of the threads from the plane surface will indicate the depth of the foreign body from that surface of the part which was in contact with the plate during exposure; and, by setting up a perpendicular

from each of the cross-lines in turn, the horizontal distance of the point from each may be measured.

By means of the small movable scale shewn in Fig. 65 both vertical and horizontal distances may be measured. Thus, to read the vertical distance, set the horizontal pointer to the point of intersection and read its height on the vertical scale: to read the horizontal distances, set the base of the vertical scale to each of the cross-lines in turn, opposite to where the threads cross, set the pointer by moving it lengthwise so that its point just touches the intersection, then read the distance on the scale marked on the horizontal pointer itself. A simple scale and a pair of compasses can be made to serve the same end, but the arrangement described is doubtless more convenient and exact.

On the skin of the patient we have a record of the cross-wires, and of the quadrants corresponding to those on the plate, so that the measurements obtained can be readily translated into depth below a certain point on the surface, thus indicating accurately the position of the foreign body sought.

Foreign Bodies in the Eye.—This is a most important localisation, much depending on the diagnosis as to whether the foreign body be in the eyeball, or external to it. Probably the best X-ray method of eliciting this information is by using the apparatus figured (Fig. 66), which is Mr. Mayou's modification of Mackenzie Davidson's localiser.

A is a broad, solid piece of wood, extending upwards from the back of the chair D, to which it is securely bound.

B is a three-sided rectangular frame of wood sliding vertically upon the upright A, and can be fixed in position by a thumb-screw. Near each free end there is an opening large enough to hold a quarter-plate with envelopes, and into this opening fits a light wooden frame across which are stretched two fine cross-wires.

C is a similar shaped frame of wood, wider between its arms than B, supporting on each arm a horizontal-sliding tube-holder E. It can also slide vertically upon upright A, to which it may be fixed by a thumb-screw.

D is a heavy chair upon which the upright with the other parts is supported.

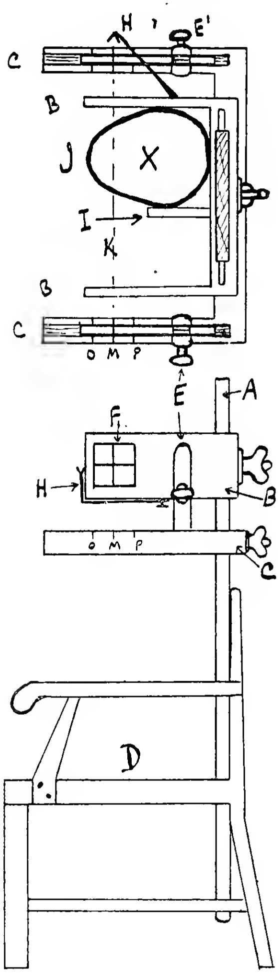


FIG. 66. — MR. MAYOU'S MODIFICATION OF MACKENZIE DAVIDSON'S LOCALISER FOR FOREIGN BODIES IN THE EYE (ROYAL LONDON OPHTHALMIC HOSPITAL).

E is one of two tube-holders which can slide backwards in a **V**-shaped groove upon the arms of C. It can also be raised or lowered by sliding the whole of C on upright

A. There is one on each side for holding the tube opposite to the right or left eye as may be required. To simplify the diagram the tube is not shown.

F points to cross-wires fitted across a wooden frame. There is one such frame for each arm of B.

H is a sighting-point. In the side view, it is pushed aside; on the view looking downwards it is pulled out in position. There is one on each side, and they are used for sighting and setting the tube. The observer looks through the **V**-notch, and adjusts the tube till he gets the focus-point mark of the antikathode in line with the crossing of the wires F on each side of B. This does away with the necessity of a screen, or other special device for centering the tube.

K indicates the centre line extending from the sight-point H through the cross-wires F to the focus point-mark of the antikathode of the tube.

I is a piece of wood that slides horizontally to clamp the patient's head to the side of the support box. The patient's head may be placed on either side of the clamp I, according to the eye which it is desired to examine.

J indicates outline of a patient's head in position for examination of the right eye. In this case the X-ray tube would be placed in holder E towards the left side, and the cross-wired window-frame of that side would be removed.

A small piece of lead wire is stuck to the lower eyelid of the eye to be examined, and carefully adjusted, so that the upper end of the wire will be exactly opposite the centre of the pupil when the patient is looking straight forward, as at a distant object.

The patient takes his position in the chair D, the head resting in box B, and to the appropriate side as in the figure. B is raised or lowered till the horizontal wires are in line with the apex of the fuse-wire which is fixed opposite the centre of the pupil, and clamp I is adjusted. Then C, bearing with it the tube, is raised or lowered, and the tube is adjusted in its holder E, till the focus-mark on the antikathode of the tube

is in line with the crossing of the wires F, the slide of the tube-holder being meanwhile in mid-position as indicated by M. A photographic plate in envelopes is then placed on the outside of the opposite opening and pressed hard against the cross-wires. For a quadrant mark we usually apply the number at the lower right-hand corner, thus numbering the plate as well as denoting its orientation.

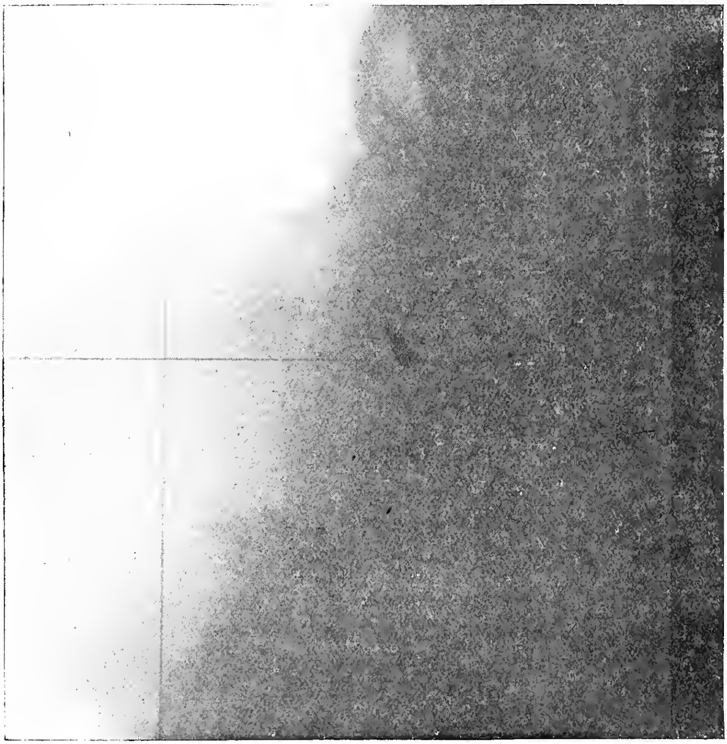


Fig. 67.—Foreign Body in the Orbit.

The cross-wire frame adjoining the tube is removed. The tube-holder slide is pushed forward till M corresponds with O (3 centimetres). The patient is directed to look straight forward at a mark on the wall at the same height as his eye; and the current is turned on for about one and a half minutes, making the first exposure. A fresh plate is then

substituted for the exposed one; the mark M is pushed backwards till it corresponds with P (6 centimetres from O), and the current is again turned on for one and a half minutes, making a second exposure.

The distance between O and P being 6 centimetres, the plates after development could, if desired, be placed in a stereoscope. The measurements are, however, generally, if not always, made by the use of Mackenzie Davidson's cross-thread localiser, which has already been described. The cross-thread localiser for eye cases is permanently set, as the

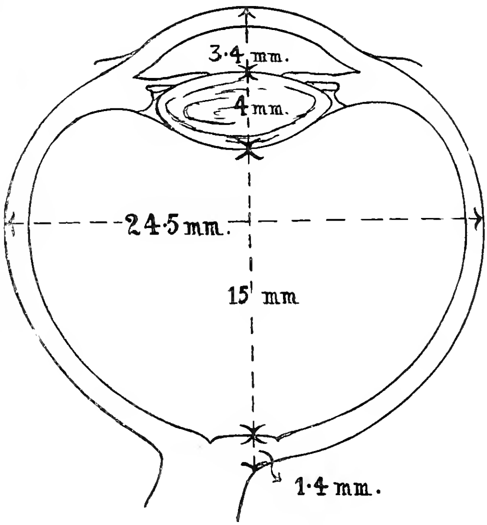


Fig. 68.

distance between the focus-point of the antikathode and the plate, and the length of traverse of the tube between its two positions, are constant for all exposures.

Fig. 67 represents the record obtained on one of two plates so exposed. From that directly we can measure the vertical position of the foreign body relative to the horizontal meridian of the eyeball, since the horizontal wire was set to coincide with that.

By the cross-thread localiser we find the position of the vertical lead wire attached to the eyelid and of the foreign

body, each relative to the vertical cross-wire, and from those we deduce the depth antero-posteriorly of the foreign body from the lead wire, and concurrently from the front of the eyeball. In making the calculations, 1 millimetre is generally allowed for the distance between the lead wire and the front of the eyeball. Then, further, by the localiser the distance of the lead wire from the plane of the plates during exposure is measured, and the distance of the foreign body from the same plane. From these two distances the position of the foreign body relative to the vertical meridian of the eye is calculated.

Thus we obtain measurements relative to the three axial planes of the eyeball; and from reference to the measurements of an adult eyeball, as given in Fig. 68, we can determine readily whether the foreign body be situated in the eyeball or in the surrounding structures, and we can indicate its position with exactitude.

The average diameters of the adult eye are:

Antero-posterior ...	... ...	24·0 millimetres.
Transverse ...	... ...	24·5 ,,
Vertical ...	... ...	23·5 ,,

CHAPTER VIII

DIAGNOSIS

It cannot be too strongly insisted upon that in this, as in all methods of diagnosis, it is essential to acquire first an **accurate knowledge of normal appearances** and of all variations within normal limits. This can be attained only by study of radiograms taken under various conditions, and most effectively so when those conditions are known at first-hand by observation of them before and during exposure of each radiogram in question. Screen-work demands a similar experience for its efficient utilisation.

In a radiogram we discern **no positive evidence** or indication of disease; all we may discern is a departure from the normal, and if an observer does not fully understand normal appearances, how can he possibly recognise or interpret the abnormal?

It should be superfluous to impress this necessity of practical experience in any branch of medical work; but the number of persons who seem to think that they are, or should be, able to read any radiogram, simply, as it were, from first principles, impels us to press this point for the benefit of those who really wish to make the most of the very valuable assistance that may be derived from radioscopic observations and records.

In all cases the evidence of radioscopy should be taken **in conjunction** with other observations or methods of diagnosis.

In certain instances diagnosis of a condition may be made from radioscopic examination alone. In some instances earlier evidence of disease is thus obtained than by any other means; but the method is of most general use in helping to

define, differentiate, or confirm conditions recognised by other means of diagnosis.

The interpretation of radiograms in general has been discussed in an earlier chapter (pp. 121-124) ; we now direct attention to that as applied to different parts of the body. To do so most effectively we give brief directions for radiographing each part, with a note of the points in the radiogram to be specially observed. Where it seems desirable, we reproduce the radiographic appearance of the part in question. A few introductory remarks are necessary, but we would advise the reader to pay special attention to the appearances reproduced, comparing them and the accompanying notes with actual radiograms.

In examining these, it must be remembered that the reproductions are positive-like prints, and that the appearances in plates or negatives will be reversed. Inasmuch as faithful reproduction of radiograms is very difficult, we would strongly advise learners to take every opportunity of studying actual radiograms.

Bones and Joints.—Examination of these forms the routine work of most X-ray installations, and comes to be relied upon more and more by surgeons as they understand more of its possible service. So definite and useful is the evidence thus obtained of obscure injuries, that we can well understand the fear expressed by a surgeon, writing recently on the subject, that younger surgeons may learn to depend upon it to the exclusion of other methods of diagnosis, of which it is well that they should also gain experience.

Possible fallacies are numerous, and should be carefully noted.

(1) The grosser lesions of **fracture** and **dislocation** are usually recognised easily from the displacement of parts as seen either on screen or radiogram ; but a fracture may exist without displacement, and such may readily be overlooked in a screen examination. **Thus, a screen examination should never be relied upon for negative evidence to refute positive symptoms.** The radiogram reproduced in Fig. 69 well illustrates the necessity of exposing a plate in all doubtful cases before expressing an opinion. The patient had some

disease of the tibia, diagnosed later as syphilitic, and was one day brought to hospital on the apparent occurrence of a spontaneous fracture. The surgeon inspected it carefully by the fluorescent screen, and was puzzled to see no evidence of a fracture. Fortunately, we followed our usual rule in such cases, and exposed over the part a plate, which on development gave evidence of a transverse fracture, without displacement or separation of the fragments.

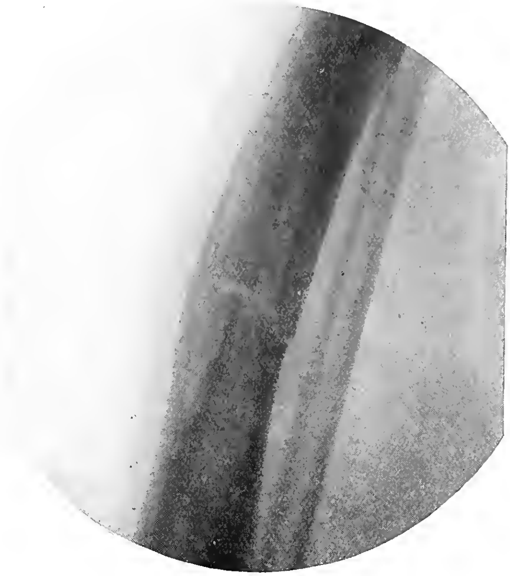


Fig. 69.

(2) **Fractures in the vicinity of joints** present some difficulty in diagnosis even by X-ray examination; but in such cases the method is of the greatest value, since other methods often leave uncertain the differentiation between fracture, dislocation, or a combination of the two. Much depends upon choosing a suitable position of the part during inspection or exposure, and upon a thorough knowledge of the normal appearances in each position of the part at the age of the subject under examination. The **age** must be specially noted, for in young subjects there is a special difficulty met with in

the presence of **unossified cartilage** in the parts, and of ossifying centres in the **epiphysis** not yet united to the diaphysis.

Where doubt exists on this point, or any other, as to its abnormality, a decision can usually be come to by comparison with a corresponding view of the same part on the other side of the patient—that is, compare right with left. Otherwise the normal line of cartilage between an ununited epiphysis and a shaft may be mistaken for a fracture or dislocation, as in Fig. 70, taken from a child of ten years of age. In the serial

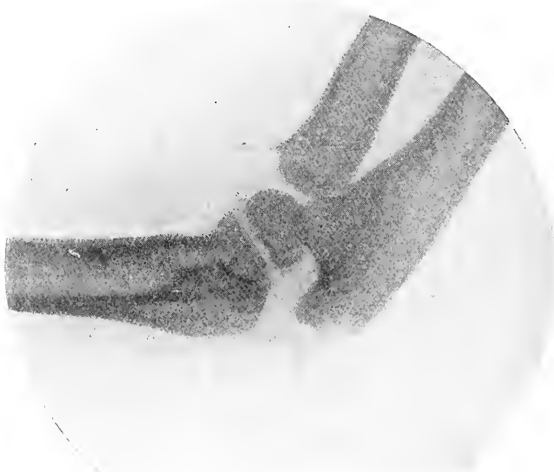


Fig. 70.

notes on each part of the body, which follow this, we have included figures illustrating the centres of ossification in each bone of the limbs, with dates of appearance and of union to the shaft. We had thought to reproduce a series of radiograms selected to shew the appearances of various joint-regions at different ages, but found that such inclusion would extend this work beyond the limits we had set. Reference to the diagrams mentioned should, however, be sufficient to guide the operator to a solution of any difficulty in this direction. A source of frequent error, due to unossified cartilage, is illustrated in Fig. 83 of the clavicle. Fig. 71, from a child of

twelve, shews an epiphysis of the os calcis which surprises most observers when they first notice it.

(3) **Reliance on a single view** of a part may lead to error, unless the part has been previously screened carefully in all positions, and the radiogram made with the part in that position found to show the lesion most plainly. On the other hand, care must be taken not to give an exaggerated view of the lesion. The danger of a single view is well illustrated in Fig. 72, where the dorso-ventral view gives no indication of

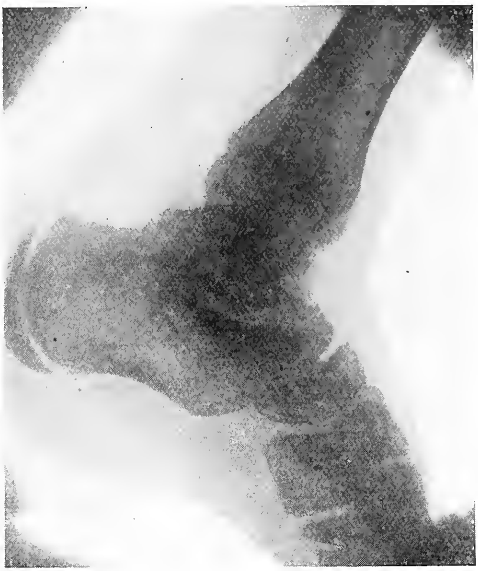


FIG. 71.—EPIPHYSIS OF OS CALCIS.

the displacement markedly seen in the accompanying lateral view, made on the same plate. (In such cases a double view may be taken on one plate by protecting each half of the plate from the rays by sheet-lead, or other opaque material, while the other half is being exposed.)

Other possible fallacies in interpreting views of special parts are referred to under those parts separately considered in the following section.

In considering radiographic appearances we make no effort

to indicate, or correlate, the pathology of the conditions considered. That can easily be done for himself by any medical reader, and we are not concerned to accommodate any others.

Diseases of bone may be diagnosed from the changes produced in contour or structure, separately or combined.

Thus rarefaction, as shewn in Fig. 73, is evidenced by the lighter shadow at the part. This corresponds to a darker

Fig. 72.

part in the negative, caused by the relatively greater amount of actinic rays permitted to pass through that part of the bone.

Conversely, **sclerosis** is evidenced by a darker shadow on the positive print, corresponding to a lighter part on the negative, that part having been protected relatively by the denser tissue. In a similar way all gradations of shadow may be interpreted into physiological or pathological variations of structure, and by combined clinical and pathological knowledge these latter may be traced to their causative condition or disease.

Periostitis is readily diagnosed from a radiogram. In acute disease, or following injury, the limiting membrane will be seen as a thin wavy line separated from the bone at the

part affected. Between that and the bone may be a less dense shadow, produced by pus collected there. From such appearance the focus of origin of the pus may be determined to the exclusion of deeper disease of the bone.

In more chronic affections the periosteum will be represented by a thickened and more dense linear shadow, separated more or less from the shadow of the bone.

Fig. 73.—Rarefaction of Bone.

Fig. 74 represents such an appearance—probably of tubercular origin.

The originating cause of the periostitis must be determined from other evidence; on that point X-rays give little, if any, guidance.

Osteo-periostitis will shew, in addition to the above, a thickening of the bone at the affected part. This condition may closely resemble clinically the early stage of a malignant disease, but the well-defined and uniform shadow of the compact bone will differentiate.

Tubercular disease of bone will produce appearances necessarily varying according to the stage of the disease. In an

early stage one may find only thickened and partly separated periosteum, as in Fig. 74, with more or less transradiant granulation tissue between that and normal bone.

Later, necrosis may become evident in the underlying bone by the appearance of rarefaction shewn in Fig. 73.

Fig. 74.—Periostitis.

A cavity may thus be revealed by the irregular shadow of diminished density cast by its retained pus and débris; or in the middle of a less dense area may appear a darker shadow cast by a sequestrum.

Fig. 75 represents an advanced stage, with widespread periostitis and osteitis of the radius. A definite area of necrosis is discernible about the middle of the bone, while the periostitis gives the shadow an irregular outline, contrasting with that of the endosteal sarcoma reproduced in Fig. 76.

Further stages of disintegration, with accumulations of pus,

may be detected from corresponding appearances. To detect the origin, and delimit the extent, of tubercular disease, a radiogram of the part is specially useful.

Syphilitic Gummata affecting bone give a characteristic appearance, shewn somewhat indistinctly in Fig. 69.

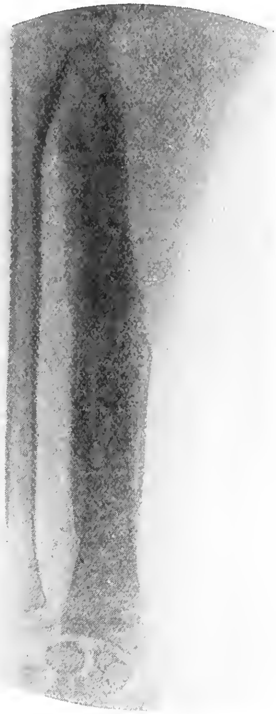


Fig. 75.—Tubercular Disease.

A gumma casts a uniform shadow of density less than that cast by bone, but greater than that cast by tubercular areas, and having a more definite outline than the latter. Encroaching on the normal bone a gumma causes rarefaction and erosion, more or less notable in a radiogram.

Sarcomatous tissue casts a shadow of density considerably less than that cast by normal bone. If the growth be **Endosteal or Central**, as shewn in Fig. 76, the shadow will be irregular in density, corresponding to the structure of bone

alternating with the invading and more transradiant neoplasm. The outline of the bone will not be much disturbed; which appearance contrasts with that of **osteo-periostitis**, the outline there being markedly abnormal, while the shadow is of uniform increased density, unless for definite areas of necrosis or abscess.

Fig. 76.—Endosteal or Central Sarcoma.

A Periosteal Sarcoma casts a shadow beyond the normal outline of the part affected. This shadow is usually of less density than that of normal bone, but the density varies in the different classes of sarcoma, fibro-sarcoma, osteo-sarcoma, etc. This abnormal shadow encroaches on the outline of the normal bone, while on its other aspect the shadow is irregular and indefinite in outline. This want of definition in outline differentiates between sarcoma and gumma, of which latter the shadow outline is regular and distinct.

An **exostosis or osteoma** may resemble a sarcoma in some respects, but the shadow of the former is uniformly dense and is definite in outline.

A **chondroma** will be similar in appearance to an osteoma, but the shadow will be less dense in character.

Rickets is evidenced by altered form of the outline of the bony shadow, but no reliable alteration in the nature or density of the shadow can be stated.

Epiphysitis is sometimes confused with rickets, but the two conditions may be differentiated by aid of a radiogram.

In epiphysitis the affected part has its outline obscured by a foggy appearance, especially involving the epiphysis, of which the outline may be quite obliterated.

Comparison with the corresponding normal part makes this abnormality more evident.

Diseases of joints are made evident by alterations in the transradiancy of their fluid contents, of their synovial membranes, or of the adjacent cartilage and bone; more advanced cases shewing further changes in contour of the latter structures.

Confusion in classification and nomenclature of joint affections renders discussion always difficult; but we have confined ourselves to description of well-recognised conditions, and do not attempt detailed differentiation, which is only possible from a full clinical history and examination of the cases concerned.

Synovitis is evidenced by a general lack of definition of the outline of the structures constituting the affected joint, along with which there is a darkening of the usual clear spaces between articulating surfaces.

This may well be expressed as a general 'fuzziness,' often discernible only by comparison with a corresponding normal joint. Where much fluid is present, the separation of the articular surfaces will also be notable. In more chronic cases the hypertrophied synovial fringes may be evident.

Arthritis shews the same changes in a further degree, with some distortion and increased density of the articular cartilages. Those latter may shew various degrees of increased density approaching a condition of ossification, or in a pro-

gressive acute case may shew appearances indicative of progressive disintegration of the joint structures.

Osteo-arthritis, as represented in Fig. 77, shews more or less distortion of the joint, along with outgrowths of ossified cartilage—the so-called 'osteophytes.'

Erosion of the articular cartilages may be evident directly from their outline, or indirectly by the closer approximation of the surfaces of the underlying bones. The outline of those surfaces is usually very distinctly marked in correspondence

FIG. 77.—OSTEO-ARTHRITIS.

with their sclerosis or eburnation, and in contrast to the less dense cancellous bone adjoining them. The fringe of osteophytes and the irregular lipped margins of the cartilages are very characteristic.

Charcot's disease may closely resemble the foregoing condition. In acute cases the greater amount of effusion, the more advanced absorption of bone, and the absence of osteophytic outgrowths, may distinguish Charcot's disease. In more chronic cases, however, those distinguishing features may not be evident, and we must rely for differentiation upon

history of onset and other points on which radiography has no bearing.

Tubercular Joint.—The appearance of this, as in the same disease affecting bone, will vary according to the stage or extent of the disease process.

In early cases we may be able to discern only a condition of synovitis or arthritis in the joint. But by paying attention to the neighbouring bone or periosteum, we may be able, from the evidence there of contiguous disease, to decide the nature of the joint affection.

If the origin be in the adjacent bone, the appearances described as indicative of that condition will be evident, with possibly a sequestrum underlying the articular cartilage.

Or the origin of the joint affection from an adjacent periostitis may be evident. If the disease originate in the synovial membrane, alterations in the adjacent bones will indicate a further stage of the disease process.

In either case the later stages of the disease will be evidenced in a radiogram by a general disappearance of outline of structures, by a reduction in density of the bone surrounding the joint, and by an indefinite mottled shadow replacing the inter-articular clear space of the normal joint.

Fig. 78 shews a case of hip-joint disease in a child. On the affected side may be noted the absence of shadow in the position of the head of the femur, which on the sound side is represented by a definite centre of ossification.

Ankylosis of a joint will be evidenced by the obliteration of the normally clear inter-articular space, that being occupied by a shadow of density corresponding to the extent of ossification of the fibrous bands or adhesions producing the condition.

Loose bodies may, or may not, be discernible by X rays, their detection depending upon their composition.

Thus, as with calculi, a negative indication cannot be relied upon in opposition to other clinical evidence. Many loose bodies are, however, sufficiently opaque to give evidence of their presence by production of shadows, more or less dense, in abnormal situations in or about a joint. If discernible on the fluorescent screen, the mobility of such bodies may be

demonstrated, but their abnormal presence is usually sufficient evidence for the surgeon.

Gout cannot be classed exactly as a joint disease, but the local manifestations of the systemic disease in and about joints render the examination of those localities serviceable, even in the diagnosis of the general condition.

Particularly in the differentiation of joint affection due to gout from the closely simulating condition due to rheumatoid arthritis is an X-ray examination useful.

Fig. 78.—Tubercular Joint.

Whatever be the correct etiology or theory of causation of gout, general or local, the characteristic process in the joint regions is a deposition of salts of uric acid.

Those salts collectively offer to the passage of X rays a resistance varying between that offered by bone and that offered by the less dense tissues of the joint. The different salts vary in density according to the base with which the uric acid is combined. The salts of calcium and magnesium are more dense than the others; and since those salts are

usually present in all gouty deposits in greater or less proportion, a distinct evidence of the abnormality is obtained on radiographic examination.

The finger joints are, for several reasons of convenience, the most desirable parts to inspect. There the earliest evidence of uratic deposit will be found on the sides of the phalanges viewed dorso-ventrally.

As shewn in Fig. 79, shadows of somewhat indefinite outline will be seen where the lateral ligaments of the joints are inserted into the bone. The normal outline of the bone may

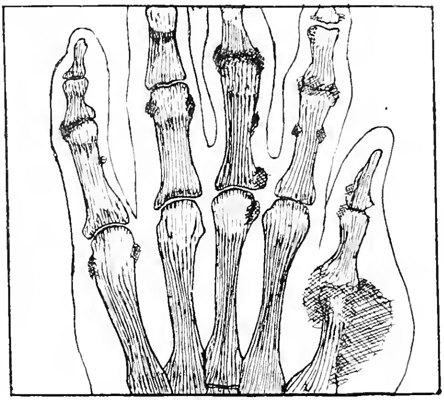


Fig. 79.—Gout in Fingers.

be seen through those shadows, or, in further advanced cases, the abnormal shadow may encroach, as by erosion, on the bone.

Later changes are seen in the articular cartilages, those becoming more opaque to the rays, while their outlines are distorted and more or less eroded.

Some parts of the bone appear more transradiant in cases of gout, apparently by change in their mineral composition; but this is a somewhat indefinite appearance, and the evidence of uratic deposit is sufficiently characteristic and distinct to rely upon in all cases.

Rheumatoid Arthritis in its earlier stages may readily be confused clinically with gout, but in a radiographic examina-

tion the absence of any deposit as described above serves to eliminate the latter from the diagnosis.

As seen in Fig. 80, the appearance of joints affected by rheumatoid arthritis (so called) is very characteristic. There is a general, though somewhat indefinite, change in the whole appearance of the bones and joints. The outlines are indistinct, and the bone tissue is on the whole more transradiant than normal, while in parts this amounts to an appearance indicating actual necrosis. Atrophy of the bones later becomes apparent. Most characteristic is the punched-out appearance

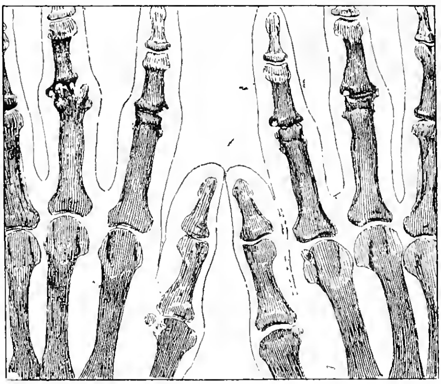


Fig. 80.—Rheumatoid Arthritis in Fingers.

of the erosions in the heads of the metacarpal and phalangeal bones, while in other joints erosion and disintegration may have proceeded to the extent of practically obliterating the joint.

Abscess or exudation about a part will obscure the outline, and produce a more or less dark shadow. Differentiation among various exudates is, however, not possible with any degree of certainty by X rays alone, and the nature of the exudate must usually be defined by other means.

Pus will usually be more circumscribed than blood or serofibrinous effusion.

Blood casts a very dense shadow, with irregular and shaded margin, while **serous** effusion may only be evident by the distortion of parts produced by its presence.

Fibrous adhesions are difficult to distinguish from normal

connective tissue, but the presence of shadows in abnormal situations may indicate them.

Special Parts.—As has been stated in an earlier chapter, it is necessary to decide for each part a **standard position**, in which it should be placed for radiographic exposure unless special circumstances dictate otherwise.

From consideration of anatomical relations, and from our experience added to that of other radiographers, we recommend the positions illustrated and explained for each part considered in this section. In every case we strongly advise that the part should be viewed by fluorescent screen before proceeding to expose a plate over it. By this means the tube, set below the patient, may be seen to be properly set and to give proper illumination, the part may be arranged to give the desired view, and the diaphragm may be suitably adjusted to include just the requisite area; then the sensitive plate should be substituted for the screen and exposure made.

In the sections which follow, the different parts of the body are taken in series and considered in relation to radiography.

There is indicated the position of each part found suitable for exposure to elicit most precisely the requisite information regarding its conformation and condition; note is made of any points in each part demanding special attention, and, where such points require it, we have reproduced figures of their radioscopic appearance.

All modern text-books on surgery are profusely illustrated with radiograms, illustrating the various fractures and dislocations, and several special atlases containing views of normal and pathological conditions are published in this and other countries.

Hence we have not deemed it advisable to attempt here any comprehensive scheme of illustration, aspiring to teach neither anatomy nor surgery. Reproductions are figured only so far as is necessary to illustrate special points referred to in the text, and are chosen, not for their general excellence or 'beauty,' but for their clear illustration of those points.

Along with the chapter on 'Photography,' this should furnish a complete practical guide to all classes of radiographic work.

Where a part is not specially mentioned (the long bones of the limbs are, we think, the only parts so omitted), it is assumed that the general principles previously discussed will serve as sufficient guide.

Teeth require the sensitive film to be placed inside the mouth; so for this region we must use what are known as '**films**,' in which the sensitive emulsion is carried on a transparent flexible base, such as celluloid or similar material.

Get or cut such a sensitive film of a size about $1\frac{1}{2}$ inches by 1 inch; fold over it black paper, or place it in a specially made envelope, then cover this completely by gutta-percha tissue, which may be sealed round it by chloroform.

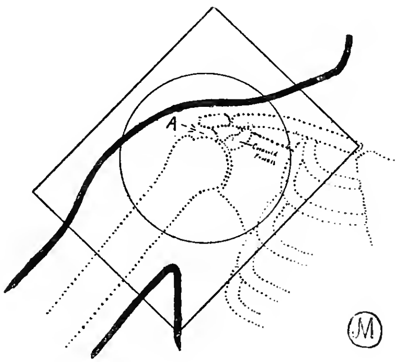


FIG. 81.—SKETCH OF POSITION FOR SHOULDER-JOINT.

Place this inside the mouth, and have it held against the part of jaw or teeth of which a view is desired. Set the X-ray tube opposite the same side and part of the face at a distance of about 6 inches from the jaw and make the exposure. By this means is avoided the superposition of the opposite jaw, which would be inevitable on a plate held outside the mouth, on the opposite side to the tube. With a mercury dipper and a medium soft tube an exposure of one and a half to two minutes ought to be correct under the conditions mentioned. This process is specially useful for locating unerupted teeth (usually canine) for the guidance of dentists.

Shoulder.—With the patient lying on his back and the tube under the table, set the tube so that the space (indicated in

Fig. 81 by letter A) between the head of the humerus and the acromion process is at a maximum. Then adjust the diaphragm to illuminate the area included in the circle shewn in the figure, with which circle the head of the humerus should be practically concentric.

Place the plate on front of the shoulder (as shewn in figure) with the upper end of its long axis pointing inwards at an angle of about 45 degrees with the middle line of the body of the patient. During exposure, exert pressure on the plate as

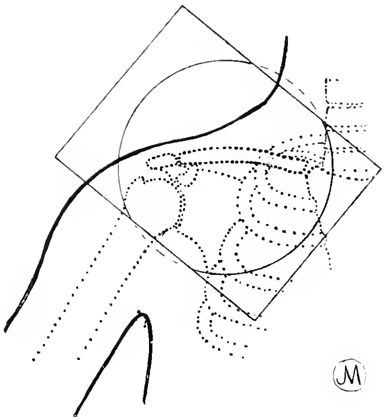


FIG. 82.—SKETCH OF POSITION FOR CLAVICLE.

it rests on the pectoral muscle and rotundity of the shoulder, endeavouring by depression of the former to keep the plate as nearly in a horizontal plane as possible.

Clavicle.—Focus the tube as shewn by circle in Fig. 82. Place as for shoulder, but with plate set so that its inner angle reaches a little beyond the supra-sternal notch and the diagonal to its opposite angle lies along the line of the clavicle. Press down on the pectoral muscle.

Fig. 83 represents a radioscopic view of a clavicle. Note at the articulation of the clavicle with the acromion process a clear triangular notch with its apex downwards. This corresponds to the intervening articular cartilage and projecting synovial membrane, which is here very redundant. The appearance shewn is quite normal, but has been frequently

mistaken by the uninitiated for a fracture of the outer end of the clavicle or a dislocation of that bone from the acromion process.

Scapula.—Place the patient on his face with the tube below. Set the tube, then lay the plate over the scapula behind. A very soft lamp will be required, and an under-exposure (as reckoned for other parts), or the thin bone of the scapula will be completely penetrated and no impression of it left on the plate.

Fig. 83.—Acromio-Clavicular Articulation.

Elbow.—Where possible, flex the joint at right angles, while the upper and lower arm lie in the same horizontal plane, and turn the hand with palm downwards.

The patient may either lie on the couch, or, kneeling at the side of it, place the arm on the couch, and lower himself till the whole upper arm rests on it.

This position will serve with X-ray tube placed either above or below the couch, and for either side of the joint, the plate being placed in contact with that condyle of which the most distinct view is desired, and the tube being set accordingly.

Fig. 85 represents a view so obtained, with the transverse axis of the end of the humerus perpendicular to the plate.

To obtain a better view of the lower end of the humerus, or possibly of the head of the radius, an antero-posterior

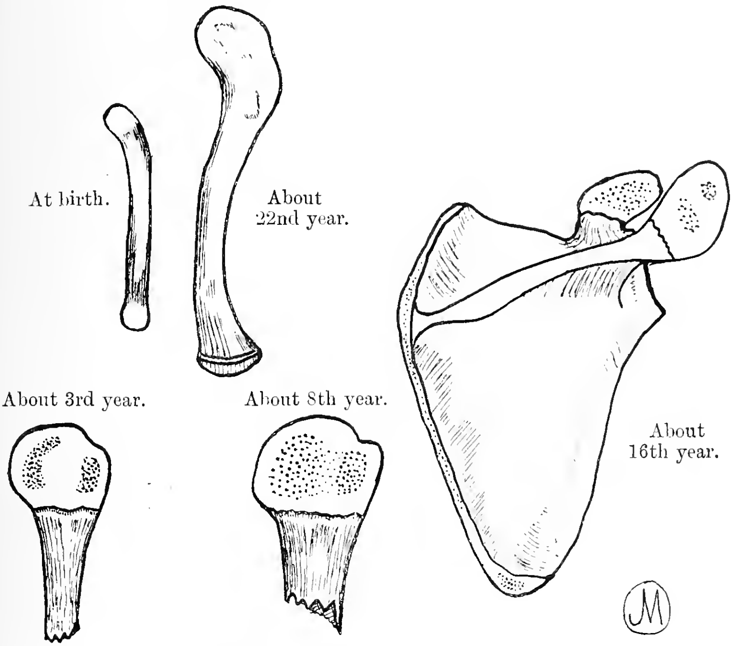


Fig. 84.—Centres of Ossification.

Clavicle.—At birth is **osseous** in its **shaft** and **cartilaginous** at **both ends.** **Acromial end** ossifies from the shaft. **Sternal epiphysis** appears about the eighteenth to twentieth year, and unites to the shaft about the twenty-fifth year.

Scapula.—Note the **separate centre** for the **coracoid process**, which appears in the first year, and unites to the body about the eighteenth year. There is also a second separate centre (subcoracoid), which appears about the tenth year, and forms the base of the process and the upper angle of the glenoid cavity. In the **acromion** two epiphyseal centres usually appear about the fifteenth year, coalesce soon afterwards, and unite to the body between the twenty-second and twenty-fifth year. A centre at the lower angle and a strip along the base appear about the seventeenth year, and unite about the twenty-fifth year.

Humerus.—At **birth** only the **ends** of the bone are **cartilaginous.** The nucleus of the **head** appears in the first year; the nucleus of the **great tuberosity** appears in the third year; the nucleus of the **lesser tuberosity** appears in the fifth year, or is continuous with the greater. These nuclei join together about the sixth year to form an **epiphysis**, which unites to the shaft about the twentieth year.

view is also desirable. For this fully extend the joint (if possible), turn the palm of the hand up, lay the arm flat on

the couch with the width of the elbow parallel to its surface, and place the plate in front of or behind the joint according

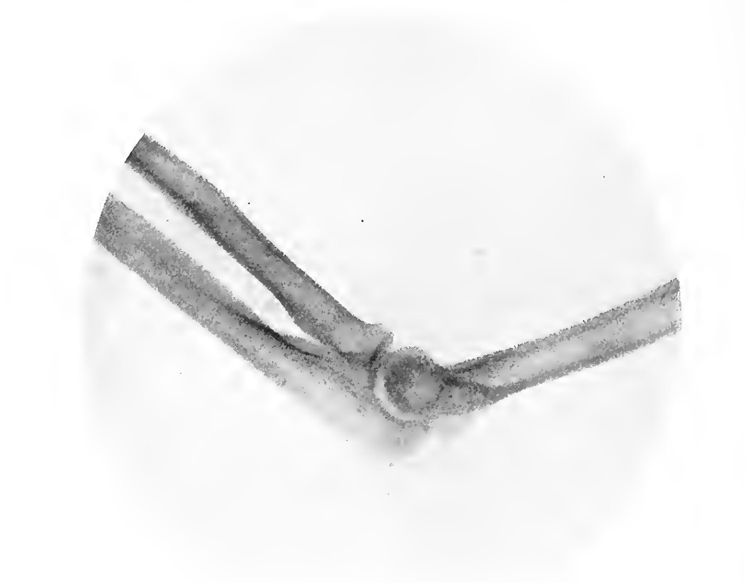


Fig. 85.—Normal Elbow.

as the tube is below or above the couch. Set the tube preferably below, so that the part may be first viewed by screen, and accurate setting thus be attained.

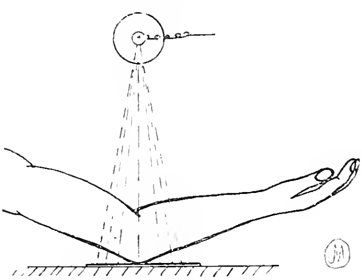


Fig. 86.—Position for Ankylosed Joint.

Where the joint is fixed in a flexed position an antero-posterior view may be obtained by resting the point of the

elbow on the centre of a plate, and setting the tube above in a position bisecting the angle of the joint, as shown in Fig. 86. The upper and lower arm should form equal angles with the plate, which should be of small size, since on a large plate parts included distal from the joint will be greatly distorted.

Fore-Arm.—For a good view set the arm with hand fully **supinated** (that is, with palm upwards) since in that position

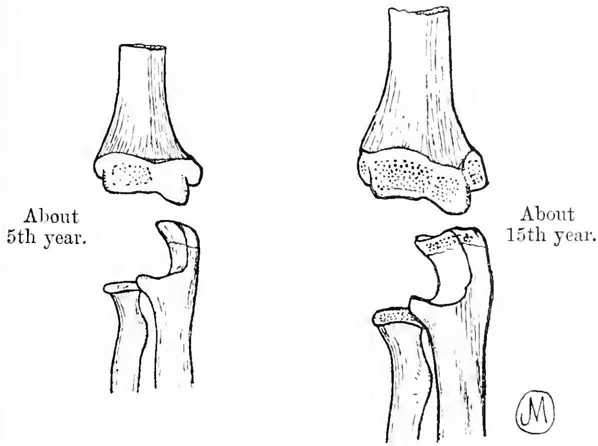


FIG. 87.—CENTRES OF OSSIFICATION.

Humerus.—A nucleus for the **capitellum** appears in the third year; a nucleus for the **internal condyle** appears in the fifth year; a nucleus for the **trochlea** appears in the eleventh or twelfth year; a nucleus for the **external condyle** appears in the thirteenth or fourteenth year. The **internal condyle** forms a **separate epiphysis**, which unites to the shaft in the eighteenth year. The **other three nuclei coalesce** to form an epiphysis, which unites to the shaft about the sixteenth or seventeenth year.

Radius.—A nucleus appears in the head about the fifth or sixth year, and the epiphysis unites to the shaft about the seventeenth or eighteenth year.

Ulna.—A nucleus appears near the tip of the olecranon in the tenth year, from which a small epiphysis forms, and unites to the shaft about the twentieth year.

the radius and ulna are parallel and each plainly seen, but do not omit to view the part also in the other position for possible displacement (see Fig. 72).

Wrist.—With injury in this region the part should be carefully screened in all positions to detect possible fracture or dislocation of the radius, ulna, or carpal bones, and to decide the proper position for a radiogram to shew most clearly the

lesion present. As a rule, the best view is obtained with the plate placed on the back of the joint, with some pressure applied. Intimate acquaintance with the anatomy and surgery of the articulation is essential to diagnose some of the obscure lesions here met with, many of which are very difficult or impossible to diagnose by any other means. We are tempted to reproduce views of various carpal injuries, but reproduction so obscures the slight differentiation relied upon, that we fear little would be gained from such views. Those views we have

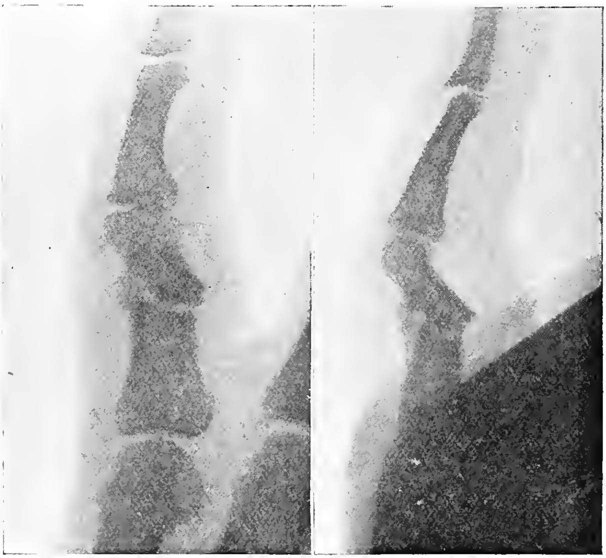
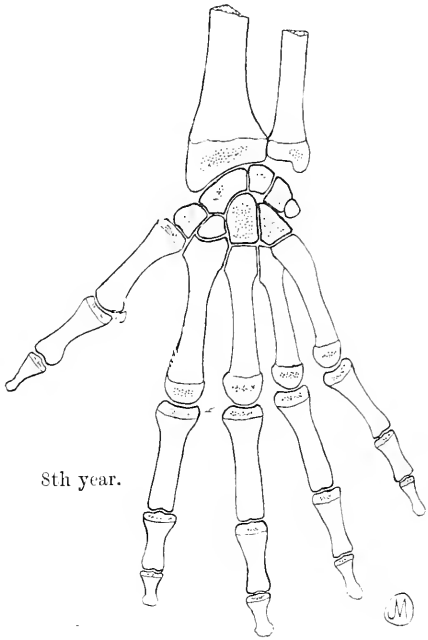


Fig. 88.—Double View of Fracture of Finger.

seen reproduced elsewhere of this region confirm us in this opinion, for in practically all the cases the reader has to depend on the letterpress description of the figure to ascertain what is represented. From surgical diagrams one will obtain much aid in interpretation, but in that he can become proficient only through experience.

Fracture of the lower end of the radius, with or without separation of the ulnar styloid (Colles's fracture), is a familiar injury met with. Impaction of the shaft of the radius into the cancellous tissue of the lower fragment may obscure the

true nature of the lesion, but in a good radiogram evidence of this will always be found, though a screen view may not reveal it.



8th year.

Fig. 89.—Centres of Ossification.

Radius.—Nucleus appears about the end of the second year. Epiphysis unites to the shaft about the twentieth year.

Ulna.—Nucleus appears in the fourth or fifth year. Epiphysis unites to the shaft about the twentieth year.

Carpus is entirely cartilaginous at birth. A nucleus appears in the **os magnum** in the first year ; a nucleus appears in the **unciform** in the first or second year ; a nucleus appears in the **pyramidal** in the third year ; a nucleus appears in the **trapezium** in the fifth year ; a nucleus appears in the **lunar** in the fifth year ; a nucleus appears in the **scaphoid** in the sixth or seventh year ; a nucleus appears in the **trapezoid** in the seventh or eighth year ; a nucleus appears in the **pisiform** in the twelfth year.

Metacarpals and Phalanges.—Each has one epiphysis, of which the nucleus appears from the third to the fifth year, and which unites to the shaft about the twentieth year. The **inner four metacarpals** have the epiphysis at the **distal extremity.** The **first metacarpal** and the **phalanges** have the epiphysis at the proximal extremity. The first metacarpal may also have a distal epiphysis at the age of seven or eight years.

Fig. 72, on page 152, is an interesting radiogram of this part, and enforces the caution (which cannot be too often repeated) not to depend upon a single view of any part.

Hand.—Apart from the carpal articulation, radiography of the hand presents no special difficulty. The best view is ordinarily obtained with the plate on the back of the hand, closer apposition to the bones being possible on that aspect.

Injuries to the metacarpal bones are occasionally difficult to diagnose precisely without the assistance of X rays, and even phalangeal lesions call at times for elucidation. Fractures near the joints may thus be differentiated from dislocations.

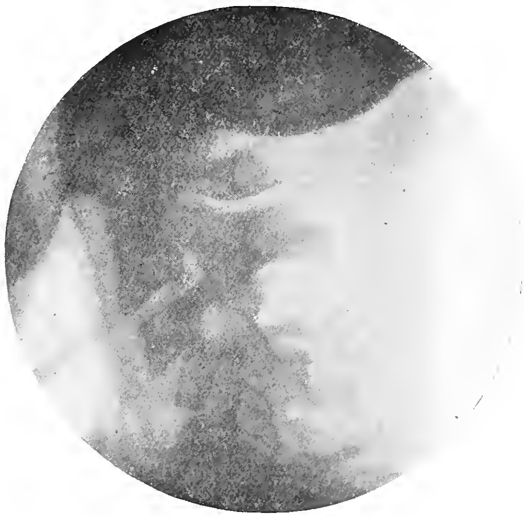


Fig. 90.—Fracture-Dislocation of Cervical Vertebræ.

Fig. 88 reproduces a radiogram of a fracture not previously diagnosed, though of some duration, persistent swelling obscuring the actual lesion.

At times the hands may be radiographed for evidence of the nature of systemic disease. Thus, as in Figs. 79 and 80, on pp. 161, 162, and as described there, the diagnosis between gout and rheumatoid arthritis may be assisted.

Spine.—With the patient on his face, the tube set under, and the plate laid over the proper region, a view of the vertebræ may be obtained.

Thus fracture, dislocation, necrosis, or abscess may be revealed and located. In seeking the two latter a careful

screen examination should be made of the whole length of the spine, or serial radiograms made, before expressing an opinion of their absence, since localising symptoms may give little or no true indication of the region to inspect. A side-view may also be valuable in any of those conditions, but the observer must remember the distortion produced by the necessary

Fig. 91.—'Pott's Disease.'

distance of the plate from the vertebræ in this position. Fig. 90 shews the radiographic appearance of a fracture-dislocation of the cervical vertebræ exposed by us recently.

Fig. 91 represents an evident case of 'Pott's disease' with curvature, but it is in earlier cases, with less marked deformity, that the chief value of X-ray examination lies.

Pelvis.—With the patient on his back, set the tube below as guided by viewing the shadow on the screen, so that the sacro-coccygeal articulation lies at the centre of the circle made by the diaphragm. The position is shewn in Fig. 92, which reproduces the radiographic appearance of a pelvis so exposed, and from which it may be seen that the shadow produced is a somewhat distorted image of the bony pelvis. In this instance the distortion is useful, since it throws the rami clear of the sacrum, and allows a fracture to be more readily observed.

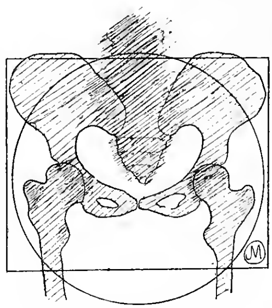


FIG. 92.—POSITION FOR PELVIS.

To detect fracture of the rami, the plate (10 × 12 inches) should be so placed that the symphisis pubis is apposed to it about the junction of the middle and lower third of the plate's width.

This is the most useful view for general purposes, but may be modified in special cases.

To procure a view of the bladder to aid the diagnosis of calculus, the method is described later (see p. 185).

For measurement of the pelvic brim or inlet many methods have been devised, but none of those seem satisfactory.

The principle of orthodiagraphy, as explained later, might be applied with advantage to this problem, but we have not so far found opportunity to test this suggestion practically, nor have we seen it proposed elsewhere.

Hip.—Let the patient lie on his back with both legs extended. Unless the nature of the lesion forbid, tie the two feet together so as to maintain inward rotation of the limbs.

This rotation brings the femur necks horizontal, thus presenting their greatest length, and, along with the great trochanters, brings them closer to the plate in front.

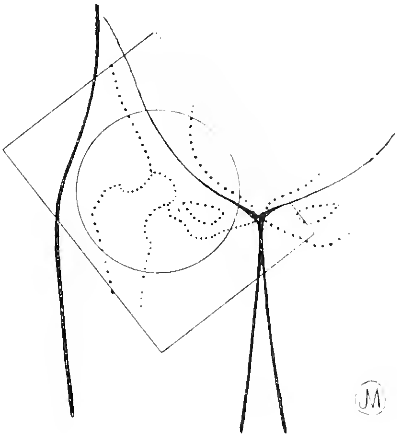


Fig. 93.—Position for Hip-Joint.

If necessary for steadiness, tie the knees also together, and support the feet in a central position by placing some heavy

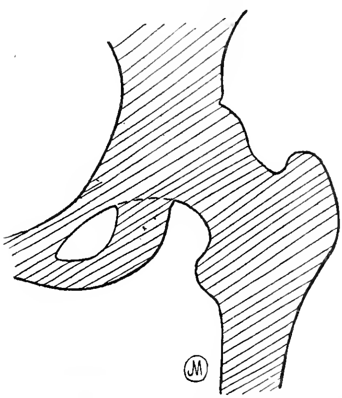


Fig. 94.—Diagrammatic Radiogram of Normal Hip.

object against them on either side. Do not attempt to get a view of both hips on one plate; the unavoidable distortion of such renders the view valueless.

Set the tube so as to have the circle of the diaphragm, including a view as shewn in Fig. 93.

Place the plate, as shewn, over the front of the joint, with its long axis parallel to the fold of the groin, and put pressure upon it so as to bring the edge which lies on the abdomen down nearly to the same horizontal plane as the other edge. A plate of 'whole-plate' size ($8\frac{1}{2} \times 6\frac{1}{2}$ inches) readily includes all that is required in a view of a hip-joint, but for a more inclusive view a plate 10×12 inches may be used.

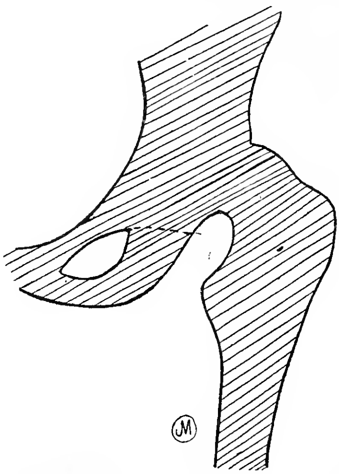


FIG. 95.—DIAGRAMMATIC RADIOGRAM OF ABNORMAL HIP.

It is important to include in the radiogram a clear view of the obturator foramen, since the line of its upper border shadow is made an important index in deciding the position of the head and neck of the femur.

From Fig. 94, which represents a normal hip-joint, it may be seen that the lower border of the neck of the femur forms a continuous curve with the upper edge of the foramen. Any displacement of the upper end of the femur, due to fracture, dislocation, or disease, will, of course, disturb the relation so projected in shadow, and the lack of continuity of the parts of this curve will indicate the abnormality. In Fig. 95, which is from a case of tubercular disease of the joint, with absorption of bone, this may be noted.

The hip-joint being a part of which it is rather difficult to obtain a view with clear differentiation, this plainly visible index is very useful.

Knee.—The position of the plate on this joint must be decided according to the information required, bearing in mind that the plate should be closely apposed to that aspect of which the most distinct view is desired.

It is possible to make a radiogram with the plate on any aspect of the joint, and the most suitable position should be decided from a careful examination by the fluorescent screen. The tube should be set, as a rule, opposite the line of the

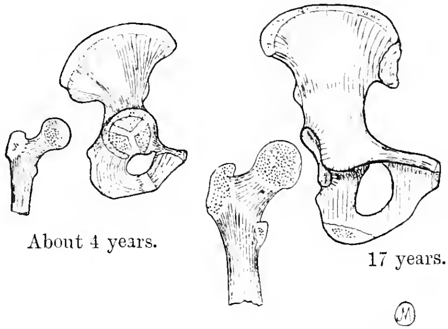


FIG. 96.—EPIPHYSES ABOUT HIP-JOINT.

Pelvis is largely cartilaginous at birth, ossification proceeding from the three centres—**ilium, ischium,** and **pubis. About puberty** epiphyses form in the **ischial tuberosity,** the **anterior inferior spine** of the ilium, at the **symphysis pubis,** and in the **iliac crest.** These **unite** with the main bone about the twenty-fourth year.

Femur.—At birth the head and neck are wholly cartilaginous. In the **head** a centre appears **in** the first year, and unites about the nineteenth year to the neck, which ossifies from the shaft. In the **great trochanter** a centre appears in the fourth year, and unites to the shaft about the eighteenth year. In the **small trochanter** a centre appears in the fourteenth year, and unites to the shaft about the seventeenth year.

joint, so as to send its central ray clear through between the articulating surfaces and produce on the radiogram a clear separating-line in all positions.

Ankle.—Here, too, we have a choice of position, which ought to be decided in a similar way to that for the knee. But of the joint the clearest view is obtained in a special position here described.

Place the patient either sitting on cushions of suitable height, or kneeling upon his sound knee on the couch, with the

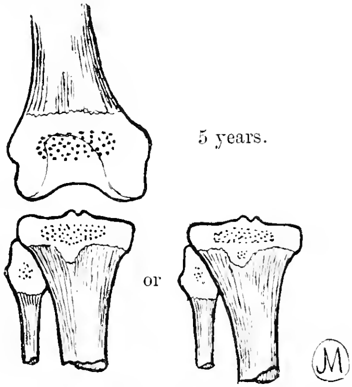


FIG. 97.—EPIPHYSES ABOUT KNEE-JOINT.

Femur at birth has a small centre of ossification in the lower end, which unites to the shaft soon after the twentieth year.
Patella ossifies from a single centre, which appears during the third year, ossification being completed about the eighteenth year.
Tibia at birth has a small centre in its upper epiphysis, which unites to the shaft about the twenty-second year. The **tubercle** is occasionally formed from a **separate centre.**
Fibula at birth is cartilaginous at both ends. A centre appears in the head about the fourth year, and unites to the shaft about the twenty-fourth year.

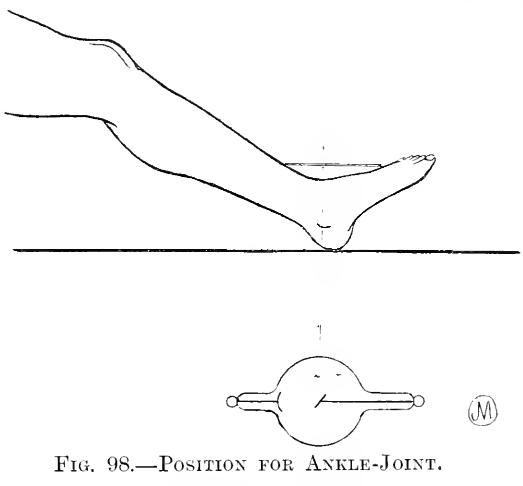


FIG. 98.—POSITION FOR ANKLE-JOINT.

leg to be radiographed stretched out in front of him, and the heel resting on the level of the couch as shewn in Fig. 98.

Place the fluorescent screen across the front of the ankle, and illuminate from the tube set vertically under the heel. Then manipulate the position of the foot until on the screen is seen a shadow of the astragalus, with a clear space round

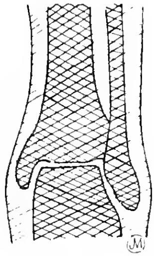


FIG. 99.—VIEW OF ANKLE-JOINT IN POSITION SHEWN IN FIG. 98.

the three sides of its articulation with the tibia and fibula, as seen in Fig. 99. After setting thus, a sensitive plate should be laid as shewn in Fig. 98, and the exposure made.

In such a view a fracture of the astragalus or either malleolus may be readily detected; while, in addition, any

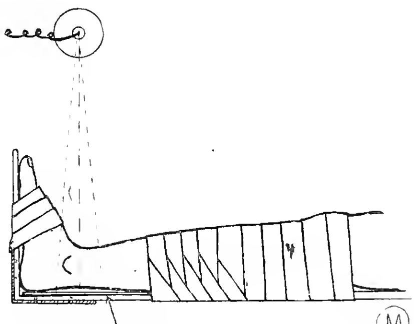


FIG. 100.—POSITION FOR ANKLE-JOINT, WITH POSTERIOR SPLINT.

separation of the tibia and fibula by tearing of the interosseous ligament may be observed in a way possible in no other position.

This part is often made difficult to radiograph by the presence of iron in a posterior splint which we may not wish

to remove. Usually the obstruction is in the form of an angled strip connecting the foot-piece to the longer part of the splint. The above position is in such a case difficult or impossible without removal of the splint, though in some cases we have managed to dodge the obstruction.

If a view from either side be unsatisfactory, the bandages should be loosened from the lower part of the splint until it is possible to gently push a plate in between the limb and the

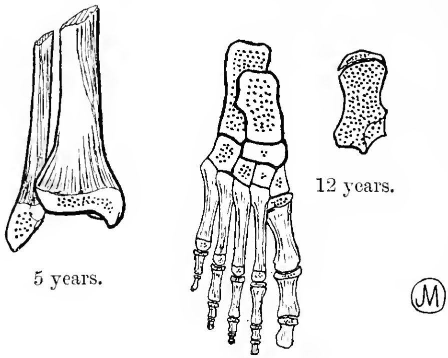


FIG. 101.—EPIPHYSES ABOUT ANKLE-JOINT.

Tibia at birth is cartilaginous at its lower end, in which a single centre appears in the second year, and unites to the shaft about the nineteenth year.
Fibula at birth is also cartilaginous in its lower end. A centre appears in the second year and unites about the twenty-first year.
Tarsal bones ossify each from one centre; the os calcis has in addition an epiphysis posteriorly. The centre of the **os calcis** is apparent at birth; the centre of the **astragalus** is apparent at birth; the centre of the **cuboid** appears about time of birth; the centre of the **external cuneiform** appears in the first year; the centre of the **internal cuneiform** appears in the third year; the centre of the **middle cuneiform** appears in the fourth year; the centre of the **navicular** appears in the fourth or fifth year; the **epiphysis** of the **os calcis** appears about the tenth year, and unites to the main bone about the sixteenth year. The **metatarsals and phalanges** have each one epiphysis, which begins to ossify from the third to the eighth year, and which unites to the shaft between the eighteenth and the twenty-first year. The four **outer metatarsals** have the epiphysis at the distal extremity; the **first metatarsal** and the **phalanges** at the **proximal**. The first metatarsal may have a distal epiphysis in addition, and the fifth metatarsal may have a second epiphysis in its tuberosity.

splint, as shewn in Fig. 100. Then, setting the tube in a suitable position above the limb, the exposure may be made. In a similar manner an antero-posterior view might be obtained of the foot or of any higher part of the leg without removing the splint.

Abdomen.

Abdominal diagnosis is not much facilitated by the aid of radioscopy, unless in defining the presence of calculi in kidneys or bladder.

The **outline of a stomach** may be viewed by giving to the patient previously a large dose of a salt of bismuth, preferably mixed with some food, such as bread and milk. This powder coats the walls of the stomach, and reveals the outline as a shadow on the fluorescent screen. Until physicians decide what dimensions constitute a 'dilated' stomach this absolute measurement is not of much value; for, where the dilatation is so great as to be beyond doubt pathological, other symptoms will have already indicated the condition clearly enough.

Œsophageal strictures or **diverticula** may be located by a similar method, or by passing a metallic bougie till arrested, then viewing or making a radiogram of it in that position. This view should be made in the left posterior oblique position, described at the end of the section on thoracic diagnosis.

Intestinal obstructions are occasionally thus sought for, but such work is yet but experimental (see footnote).

Tumours in the abdomen may or may not be revealed and partially located by their shadow. A radiogram will shew little more than a more or less defined shadow where no shadow should be normally present. A screen examination will give more information by noting the movements of the shadow relative to respiration, and by observing its continuity or otherwise with normal shadows of the region.

Abnormal conditions of the **liver** may be revealed; but, as a rule, only when the shadow projects beyond the normal outline of the liver shadow, since that organ is so dense as practically to defy differentiation. Thus, the presence of hydatid disease or chronic abscess may be confirmed, but we have hitherto failed to diagnose between these two conditions. In this region we have found screen examination much more satisfactory than radiography, the abnormal presence of shadow being all the information an observer need look for.

Note.—For recent methods of radiography of these regions see note on 'Teleradiography' on p. 219, also article in the *Archives of the Roentgen Ray* for October, 1908, where two remarkable radiograms are reproduced illustrating gastric and intestinal movements.

In the **kidneys** the usual quest is for calculi. In a person of ordinary girth one may confidently expect to secure evidence of a renal calculus, if one be present, provided careful attention be paid to the points noted later. The composition of the calculus determines to some extent the likelihood of its casting a perceptible shadow, oxalate of lime being most readily observed, while phosphatic calculi cast perceptible but less definite shadows, and uric acid or urate of ammonia calculi are so transradiant as to be readily missed. In the *British Medical Journal* of January 20, 1906, an instructive radiogram is reproduced shewing the relative opacities of different calculi. (This is illustrative of a paper by Mr. Mackenzie Davidson on p. 137 *et seq.*). Where the evidence of a radiogram is positive the diagnosis may be confidently relied upon, but where negative it should be doubted unless all the landmarks prescribed later are clearly defined. Even when the radiogram seems as reliable as could be desired, operation should not be refused on its negative evidence if other symptoms are strongly indicative of the presence of a calculus. Besides confirming the diagnosis of its presence, the location of the calculus may considerably reduce the severity of the operation for its extraction. A screen examination can in no case be relied upon for final evidence of the presence or absence of a renal calculus. A fluoroscope has been used to view a kidney during operation, the kidney being brought out on the loin for the purpose, but so far as we know this method has not been adopted to any extent.

The **bladder** and **ureters** may be similarly investigated by radioscopy for presence of calculi. In the latter position stereoscopic views are preferable to locate the calculus; in the former the calculus is, of course, movable, and its detection is sufficient. Directions for radiographing ureteral and vesical calculi are given later, but, despite the apparent simplicity and certainty of the diagnostic process in the latter region, it is found in practice to be somewhat unsatisfactory.

This is probably due jointly to the position and to the phosphatic composition of most of the calculi found there.

Kidneys.—Before proceeding to radiograph this region, make sure that the patient has had the bowel recently and

thoroughly emptied, otherwise confusion of shadows is likely to result. It is better to postpone the exposure than to proceed with the bowel possibly occupied by fæcal masses, which may simulate, or at least confuse the evidence of, the presence of calculi.

That secured, place the patient on the table, lying with his face downwards, and the tube placed below as shewn in Fig. 56, on p. 97, where will be found some notes bearing on procedure necessary for this part. Under him, crossing the space between the iliac crests and the lowest ribs, place a cylindrical air-pillow, as shewn also in Fig. 56, and more particularly in Fig. 102. This diminishes the forward lumbar

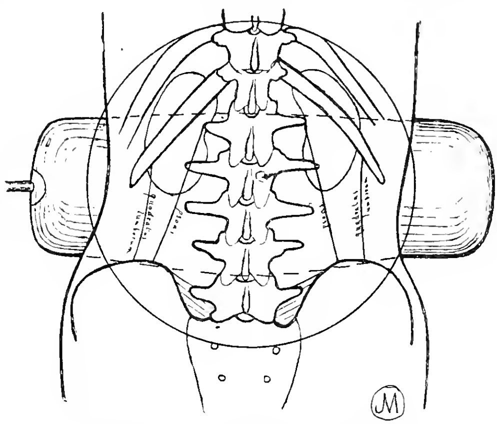


Fig. 102.—Position for Kidneys.

curve and presses the kidneys backwards, whilst it further serves to restrict their movement, which normally occurs in consonance with the respiratory movements of the diaphragm. Guided by the view on a fluorescent screen, adjust the tube below till an area is illuminated, as shewn by circle in Fig. 102, which includes a narrow portion of the iliac crests and the two last ribs on either side.

Then replace the screen by a large plate 10 × 12 inches (or larger if desired), and hold this firmly in position by pressure while an exposure is made.

This pressure may be suitably exerted by a rigid flat board faced with lead, and on that further pressure may be added manually or otherwise. The patient's weight acts, of course,

as a compressing force on the part bearing on the air-cushion, and by this method we can dispense with any of the elaborate compressors recommended by manufacturers.

As noted in the chapter on 'Photography,' it is advisable to use a moderately soft tube, or otherwise a calculus—specially if it be of a softer variety—may be entirely penetrated, and no record of it be left on the sensitive plate.

We find it better also to give a fairly long exposure—from two to four minutes, according to the stoutness of the patient exposed, and, of course, varying inversely with the strength of current employed.

It is always preferable to include both kidneys in one view for the sake of comparison, and also because the symptoms noted are sometimes found to indicate the wrong side as the situation of the lesion. Much after-confusion may be saved here by remembering the earlier instruction to place on one definite corner of the plate a metallic object which will be imprinted on the plate during exposure, and enable us subsequently to differentiate right and left sides without hesitation.

If one kidney shews abnormality in the larger plate, and a more defined picture be desired of it, a plate may be exposed over that side with the tube centred, and the diaphragm contracted, to include the abnormal organ alone.

If there is doubt in the diagnosis, a second examination should be made after some days, during which time thorough evacuation of the bowel should be secured by purgatives supplemented by a high enema.

In a reliable radiogram of this region there should be plainly discernible on each side shadows of the iliac crest, of the two last ribs, of the quadratus lumborum muscle, and of the psoas muscle. The kidney outline is also usually visible, but if the other four landmarks are not traceable the radiogram should not be relied upon. Fig. 102 shews diagrammatically the landmarks mentioned.

The original negatives only can be relied on for results, as appearances discernible on those may be incapable of reproduction on prints.

Ureters. — Radiography of the ureters presents great

difficulty, and results in search for calculi in them are still very uncertain. If present towards the higher end of the ureters, calculi may be detected in a plate exposed as directed for the kidneys. The lower parts must be exposed differently in order to clear the pelvic shadow, as described for the positions mentioned below for radiographing the bladder.

Other structures in the region of the ureters may cause doubt and confusion in interpreting a radiogram.

Thus, calcified glands along the border of the vertebral shadow or in the pelvis, as well as phleboliths in the veins or calcified portions of arterial walls, may simulate the appearance of calculi. To eliminate those an opaque bougie may be passed up the ureter, and the relation of the suspected shadow noted to that of the bougie. Stereoscopic views of the part, especially with bougie in position, assist the diagnosis and location materially.

A number of interesting radiograms illustrative of this method are reproduced in the *British Medical Journal* of June 17, 1905, in connection with a most instructive lecture by Mr. Fenwick.

In that he states that the three great features of ureteric stone shadows, as distinct from the conditions which simulate them, are: they lie in the line of the ureter, their outlines are sharp, and their shapes are more or less oval.

He also refers to the assistance obtained by filling the bladder with air, which makes the pelvic space more trans-radiant, and indicates the outline of the bladder on the radiogram. This may be done, as he says, by merely passing a catheter and elevating the pelvis.

Bladder.—For a joint view of the bladder and lower part of the ureters the patient should be placed on his back, and the tube set below so as to throw its rays upwards in a line about parallel with the axis of the brim of the pelvis, so as to clear the bony walls of the cavity. Thus, with the centre of the tube close to, and about an inch beyond the tip of, the coccyx, raise a little that end of the tube towards the patient's feet, as shewn diagrammatically in Fig. 103.

Then place a plate, 12×10 inches, over the abdomen, with its length across, its upper edge about the level of the umbilicus,

and its lower edge slightly overlapping the symphysis pubis. Depress the upper edge of the plate so as to inhibit its move-

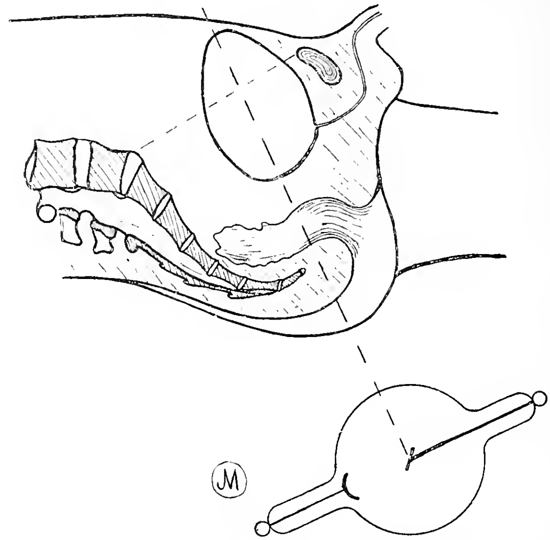


Fig. 103.—Position for Lower Part of Ureters and Bladder.

ments with respiration by exerting pressure on it either by manual pressure, by superimposed weight, or by strapping.

For the bladder alone it is preferable to lay the patient on his face and place the plate under him, since by gravity a

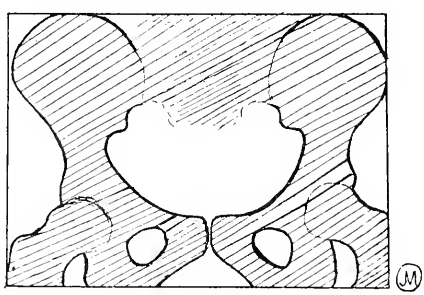


Fig. 104.—Shadow of Pelvis in Radiogram of Bladder.

calculus will then come to lie in close apposition to the plate. The same directions as to setting of the tube and plate relative

to the patient apply here as in the other position, and if the patient's own weight be not considered sufficient for compression, a transradiant band may be passed across his back and fastened to each side of the table so as to exert pressure.

The form of outline of the shadow obtained will vary with the age and sex of the patient; but the endeavour should be to secure as large and as clear a space as possible in the centre representing the cavity of the pelvis. Fig. 104 represents diagrammatically the form of shadow usually obtained under average conditions.

Thorax.

Thorax.—On this part much attention is focussed at the present time by radiographers, but the limits of variation in the normal are probably not yet wholly defined. Indications of abnormality being entirely relative, considerable experience is required to form a definite opinion on views of this region, and wide experience enjoins caution in expression of such opinion. Valuable assistance may, however, be derived from radioscopic examination in conditions suspicious of aneurysm, phthisis, and some other conditions illustrated later. To those illustrations are appended notes descriptive of them, but attention must first be directed to normal appearances and to general methods of examination.

It is important to observe the extent and nature of the **movements** of the heart and diaphragm, as well as to note the outline and nature of the shadows cast by the thoracic contents. Hence the fluorescent screen is much employed in examining the thorax, and to a practised observer may give more information than a radiogram, especially concerning the functional condition of the organs. Apart from the movements, the appearances on a screen or radiogram are similar, but are more exactly observed on the permanent record. From the thickness of the part there is necessarily a considerable distance between the sensitive plate and some of the parts casting shadows upon it. Thus the record obtained in a radiogram is a considerably distorted view of the parts in question; and since the various organs lie at different levels, their relations are somewhat distorted also. This is more

fully discussed in the chapter on 'Orthodiagraphy,' which is a method devised to obviate the distortion mentioned. The fact of distortion must always be borne in mind in thoracic diagnosis, and it has doubtless much influence in causing the uncertainty mentioned at the beginning of this section.

If a radiogram be desired to shew the **heart** plainly, the plate should be placed **in front** (see Fig. 105). If it be more particularly desired to view the **lung apices**, the plate should be placed **behind** (see Fig. 106). As to the relative advantages of the erect or prone position of the patient there is much variety of opinion; but, provided that the radiograms are contrasted with the proper normal appearance for the position employed, we cannot see that there is much to choose between the views obtained. For screen work the patient should certainly be viewed in both positions, but for radiography we adhere to the prone position, as dictated by reasons of convenience.

The screen should be placed in succession in front, behind, to the left side, and in what is known as the 'right anterior oblique' position, the tube being set in each case accordingly. Of the last position a special description is given later (see Fig. 116, on p. 206).

In radioscopy or radiography of the thorax, especially for examination of pulmonary conditions, too hard a tube must not be used, or many of the finer details of structure, on which diagnosis here largely depends, may be lost by over-penetration. These finer details can certainly be more efficiently observed on a radiogram, since the cumulative effect produced there enables the eye to detect appearances which it may quite fail to discern on the screen.

In Fig. 105 is reproduced a radiogram of an ordinary thorax, which may well be taken as an average normal, the plate having been placed in front and the X-ray tube behind. This is seen to consist of a light area, corresponding to transradiant lung on either side, and separated by a dark '**median shadow**.' This **median shadow** is cast collectively by the vertebral column, the sternum, and the heart with the great vessels attached to its base. The **right border** is almost vertical, with a slight angular deflection outwards below its

middle. It is made up from above downwards by the **spine**, the **vena cava superior**, and, under the obtuse angle, the **right auricle**, the shadow of which joins that of the diaphragm or liver.

It is a general and useful convention to consider that this right border should not, under normal conditions, be at any point more than ½ inch from the line of the right border of the sternum.

The **left border** is vertical in its upper part, which is either straight or with a slight convexity outwards, and corresponds

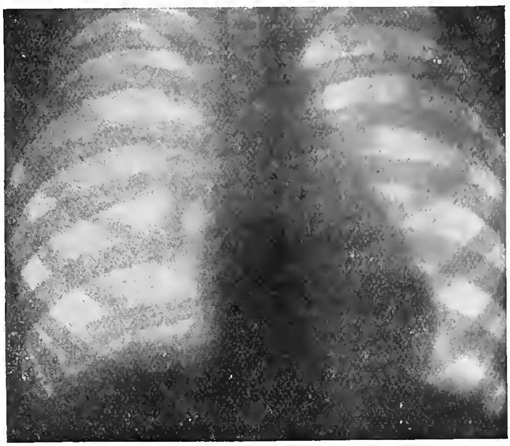


Fig. 105.—Normal Thorax, Plate in Front.

to the **spine**, the **aortic arch**, and the first part of the **descending aorta.** From its occasional convexity this part is spoken of as the 'left lateral aortic bulge,' and is more definitely viewed with the screen placed behind.

This is followed by a more marked convexity formed by the left **pulmonary artery** and part of the **right ventricle.** Sloping slightly outwards, this second part joins more or less abruptly a larger convexity, which lies diagonally and is formed by the **left ventricle.** This in turn joins the shadow of the left diaphragm and liver (see also Fig. 109 on p. 200).

Around the cardiac shadow are usually seen certain faint lines or streaks, more pronounced on the right side, which are

probably due to folds of pericardium at the junction of that structure with the parietal pleura.

Other observers ascribe the appearance to the larger pulmonary vessels, and at present the point is not settled. But the appearance must be known and noted as normal, or it may be mistaken for an indication of pathological change.

The 'median shadow' is more fully discussed in dealing with diagnosis of abnormal conditions of the heart and great vessels (p. 200), and its more exact observation is described in the following chapter on 'Orthodiagraphy.'

At each junction of the cardiac shadow with that of the diaphragm may be seen on deep inspiration a triangular space called the 'cardio-phrenic space.' This is best seen on the screen, being blurred by movements during exposure for a radiogram; and in occasional cases it may extend right across between heart and diaphragm.

In examination of the transradiant areas corresponding to lung on either side the fluorescent screen is of prime importance.

The arched shadow forming the lower limit of the thorax is usually spoken of as the diaphragm shadow, though really produced mainly by the underlying liver. It is normally a little higher on the right side than on the left, and is seen to move up and down with a piston-like movement synchronous with respiration. Under normal conditions the excursions are equal on the two sides in quiet respiration, and measure about $\frac{1}{2}$ to $\frac{3}{4}$ inch vertically. In forced respiration the left side tends to shew slightly greater movement than the right, but where inequality is noted in ordinary respiration the condition is pathological.

Thus, when one side is affected by tuberculosis, there is, practically in all cases, a perceptible diminution of the excursion on that side, and the movement may further be jerky and interrupted or undulatory. This diminution of excursion of the diaphragm on the affected side is a very early sign of phthisis, and we have been able more than once from its presence to diagnose tubercular affection of a lung, while physical signs still left it in doubt, or even seemed to refute the diagnosis. Other points in diagnosis of pulmonary tuberculosis are referred to later.

To note the lesser degrees of difference in movement of the two sides, the limits of excursion should be marked on a piece of glass or paper laid on the fluorescent screen, while that is held steadily in position. The degrees of excursion as measured by the distance between the marks on either side can then be accurately compared, and inferences drawn.

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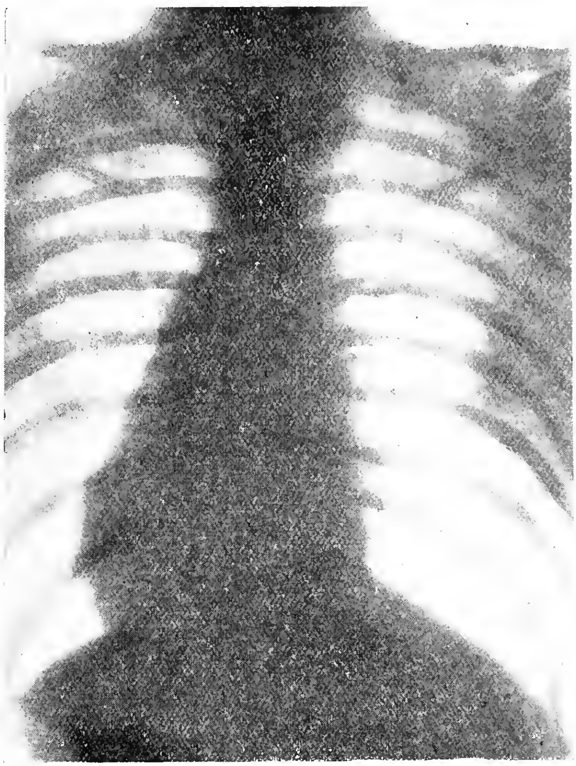

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FIG. 106.—NORMAL THORAX, PLATE BEHIND.

During deep inspiration the lungs are seen to become more transradiant, the effect being due jointly to the greater amount of contained air and to the lessened amount of blood in the capillaries.

While being viewed with the screen, the patient should be instructed to breathe somewhat deeply. In light inspiration

a dulness may be noted in one or both apices, suggestive of tubercular deposit, but on deeper inspiration this may clear up, proving the dulness to have been due merely to lack of expansion.

For observation of the apices the posterior position of screen or sensitive plate is preferable. The scapulæ may here interpose a shadow over part of the clear lung area, but they may be displaced by extending the arms above the head, when a view, as represented in Fig. 106, will be obtained.

The position and movements of the ribs should also be noticed and compared on the two sides. Impaired movement is suggestive of mischief on that side, as also is abnormal position, the latter point being illustrated and referred to later.

In all examinations much depends upon comparison of the two sides of the thorax; hence care must be exercised to see that the two sides are equally illuminated, and that by a tube just hard enough to illuminate the screen.

Further points may be elicited more conveniently from a radiogram, though most of them are discernible also on a fluorescent screen suitably illuminated. These points are indicated in the notes of reference to the subsequent series of illustrations of various lung conditions commonly met with. Before considering the actual illustrations, we suggest the relations of the appearances found to the conditions producing them in the following brief table. This makes no pretence to be exhaustive, but it is intended to be suggestive, and the reader can readily supplement it from his clinical experience:

Diminution of transradiancy	suggests	in irregular patches		especially at apices, **phthisis pulmonalis.**
				especially at bases, **congestion.**
				broncho-pneumonia.
		in delimited patches		**abscess.**
				at apices, **phthisis pulmonalis.**
			at bases	**œdema.**
				pleurisy.
				empyema.
			at root	**pneumonia** (commencing or receding).
				enlarged bronchial glands.
Increase of transradiancy		in patches		**bronchiectasis.**
				phthisical cavities (empty).
				emphysema.
		general		**pneumo-thorax** (with shadow of contracted lung).

This is supplemented in the notes to the following plates, illustrating various conditions.

Pleurisy.—It will be readily understood that any thickening of the pleura, or presence of fluid in the pleural cavity, must markedly alter the appearance of the part affected as viewed by X rays.

Acute pleurisy without effusion causes no alteration in appearance, but the **excursion of the diaphragm** will probably be affected; hence the importance of the use of the screen in all thoracic examinations is borne out.

Thickened pleura will cast a **shadow by contrast** with the unaffected parts, though not so dense as when fluid is present.

The absence of any displacement of the heart may assist the latter differentiation. Excursion of the diaphragm may be affected.

In contrast with consolidation of the lung, which may cast a similar shadow, a case of thickened pleura alone shews no change in breadth of the affected side, no change in position of the ribs known as roof-tile, and no cardiac displacement.

Effusion of fluid into the pleural cavity produces changes in appearance not readily missed or mistaken. A **homogeneous shadow** is cast, more or less dense according to the amount of fluid present, and also according to the nature of the fluid. Thus, pus casts a denser shadow than serous fluid of the same amount, but the comparison is somewhat indefinite.

With serous effusion or empyema, without the additional presence of air, the masking shadow decreases in intensity from below upwards, and its upper margin is ill-defined, especially if the lung above be compressed or consolidated, in which latter case no differentiation may be possible.

With no such complicating condition of the lung the **upper limit** of the fluid, as seen in the shadow, is usually **concave**, due doubtless to the action of capillarity, the concavity being less according to the amount of fluid present. Normal lung above this line appears very clear by contrast. **Displacement of the heart** is usually well seen, this being to the opposite side to the effusion in contrast to a case of **solid lung**, in which displacement would be towards the same side. A

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further differentiating sign between the two conditions may be found if the patient's position be altered from vertical to horizontal; when, if such fluid be present, the level will be seen to alter. This is very marked if any air be present above the fluid. Probably the most definite evidence of the presence of fluid is obtained by noting the **triangle at the outer end of the diaphragm**, where it joins the chest-wall. This is not occupied by lung unless on very deep inspiration; hence consolidated lung can never obliterate it, but fluid will early flow into it, and produce a marked change in the appearance.

Between serous fluid and pus X-ray examination does not make exact differentiation easy, since the difference in shadow is wholly one of degree.

Pneumothorax will present an appearance strongly contrasting with pleurisy, since here the affected side will be **abnormally transradiant**, unless for the small area towards the middle line occupied by the contracted lung.

Absence of respiratory movements of the chest-wall will be marked, as also will **displacement of the heart** to the opposite side.

Pyo-pneumothorax combines the appearances of the two conditions just described. The **upper level** of the dense shadow cast by the pus is **sharply defined**, and is unvaryingly **horizontal**, in contrast with the concave margin noted in pleurisy.

If the patient's position be altered, this upper limit is seen to maintain its horizontal position distinctly, and, if the patient be shaken, movements like splashing may be evident on the surface of the fluid.

Pneumonia casts a shadow varying with the stage of the disease. The density of shadow will naturally vary with the degree of consolidation, and it is interesting to note that normal transradiancy is not regained by the affected lung till some time after convalescence is established. Points of differentiation from pleuritic affections have been already

noted. In cases of central origin, where percussion may fail to detect early conditions, X-ray examination is especially useful. We have not had opportunity to examine many such cases; but our observations bear out the suggestion made by another observer that all pneumonias are really central in their origin, progressing from the root of the lung towards the more superficial parts, in which ordinary physical examination may more readily determine their presence.

Emphysema produces appearances directly opposite to pneumonia, just as it produces opposite physical signs. The

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Fig. 107.—Radiogram of Emphysema.

affected areas are rendered **more transradiant** and more extensive, as seen in Fig. 107; while **interposed objects**, such as the ribs and heart, have their shadows very **sharply defined.** The **ribs** are seen to assume a more or less **horizontal** position, and to have **little movement** even on deep inspiration. The diaphragm on the affected side is displaced downwards, and has its ordinary movement restricted. The heart, too, is displaced downwards, and assumes a more vertical position—hung, as it were, by the vessels attached to its base.

Accompanying conditions, such as caseating patches, are often impossible of detection by percussion owing to em-

physema, but in X-ray examination their detection is made easier by the increased contrast of that condition.

Pulmonary tuberculosis lends great opportunity for the radiologist who combines clinical experience with his radiology.

For evidence of early conditions X-ray examination is undoubtedly the most useful method yet known, but it cannot be relied upon apart from a knowledge of other conditions present or possible in each case. Certain other conditions may closely simulate some of the appearances about to be described as evidence of phthisis, though seldom will the combined appearances ascribed to that be produced by any other condition. Recent apical pneumonia, or pulmonary embolism and infarction with mitral stenosis, are examples of possible pitfalls, but the history and accompanying signs should enable a careful radiologist to steer clear of them.

Such history and signs must, however, always be taken note of, and, if any doubt exists, a second examination should be made after an interval of some days or weeks before a definite opinion is expressed.

In an advanced case, such as is shewn in Fig. 108, one's attention might be arrested by—

(1) The evident **change in form of the chest**. Apart from dimensions, this is evidenced by the change in **position of the ribs**, which assume an appearance of overlapping each other, hence termed 'roof-tile.' This is, however, a late change, and usually where present the case will have been already diagnosed by other means.

(2) The appearance of **patchy or mottled shading** in the areas normally transradiant and clear is very characteristic, and varies in amount and intensity according to the extent of disease present.

This shading is produced by diseased portions of the lung-tissue, **calcified** patches casting the most dense, **caseous** patches less dense, and **grey and yellow tubercles** still less dense, but quite definite, shadows.

Before physical signs are evident diseased patches may be detected by this mottled shading; and almost invariably, when a case is referred to us with suspicion of tubercle in one

apex, we discover this evidence in the other apex as well, though by physical signs that may be quite unsuspected.

Where there is **accompanying emphysema** masking the physical signs of such condition, and causing percussion to fail absolutely in its detection, an X-ray examination is particularly useful, since the appearances described above are rendered **more distinct by contrast** with the clearer areas of emphysema.

(3) As mentioned earlier, the **apical appearances** should always be checked on the screen by causing the patient to

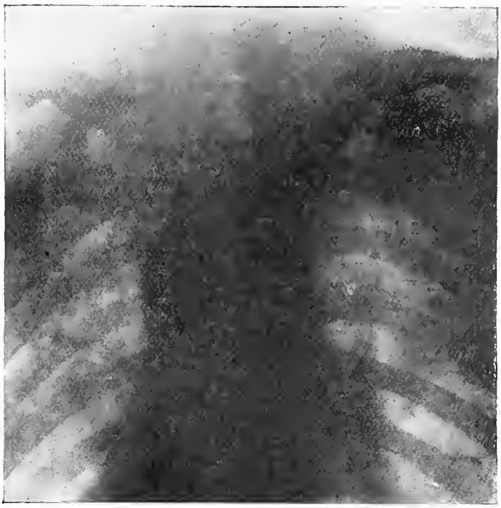
L.  R.

Fig. 108.—Radiogram of Advanced Tuberculosis.

inspire deeply, since a partial and suspicious dulness may thus be entirely cleared up, and possibility of error in diagnosis be lessened. If one or both apices refuse so to clear up, strong evidence is furnished of a tubercular condition, the stage of which must be judged from the presence and extent of accompanying conditions.

(4) **Movement of the diaphragm shadow** is probably the most valuable and most interesting observation to make relative to a query regarding presence of tubercular disease of the lungs. From the nature of the sign it can only be

observed on the fluorescent screen, and it should be so observed and measured with the screen situate on the anterior and posterior aspect in turn.

This movement may be seen to be affected even before the mottled shading described above is observed, and certainly before physical signs indicate a tubercular condition. To speak of a 'pre-tuberculous' period, as a French observer did in discussing the point at the Congress on Tuberculosis in 1902, is to put an unjustifiable strain on terminology; but in many cases the diagnosis which this sign enabled us to make has seemed to the physician more prophetic than actual. In practically all of the cases, however, in which we expressed a positive opinion the after-progress confirmed the diagnosis.

In the normal thorax the movement on each side is similar in nature and degree. On the side affected with tubercle, however, the movement, as described on p. 190, is restricted, and may be jerky, interrupted, or undulatory in character. This may amount almost to fixation of that side of the diaphragm, but it is on the less-marked degrees of restriction we depend for early diagnosis. These may be detected by measuring as described in the section above referred to (p. 191), and this should never be neglected in cases offering the least suggestion or suspicion of phthisis.

If the disease process be checked by treatment, this restriction of movement will be seen to become less as convalescence proceeds, and progress may be so gauged with some degree of accuracy.

(5) **The position and form of the heart** is described by some observers as typical in cases of phthisis, but variations are too common, we think, to admit classification of a type.

The cardiac shadow is doubtless, in the majority of cases, smaller and more vertical than usual, but how much of this change in size is due to rotation is not defined. A small-sized heart is said to predispose to tuberculosis, whilst a large heart justifies a more hopeful prognosis. This is an interesting point, but one requiring considerable elucidation before dogmatic statements can be accepted upon it.

Cavities in the lung are usually clearly definable by X rays. If air-filled, they present a clear area, surrounded by a dark

ring of shadow, produced by surrounding consolidation. If filled with pus, the shadow is dark throughout, and detection of the cavity less certain.

Fibrosis of the Lung has been referred to in the differential diagnosis of pleurisy, etc., in preceding sections. The affected part casts a dense shadow, generally uniform in character. There will be collapse of the chest-wall, with roof-tile appearance of the ribs, and the heart shadow will be seen displaced towards the affected side.

Abscess will evince its presence by a dark shadow more or less circumscribed, and its location for subsequent operation will be greatly simplified and assured by an X-ray examination.

Neoplasm in the thorax casts a dense shadow, in contrast to the transradiant lung-tissue, with density grading from its centre radially outwards. Accompanying this main shadow there will probably be other appearances, produced by accompanying pulmonary conditions such as congestion, pleural effusion, and enlargement of bronchial glands. The latter may simulate thoracic aneurysm, though the nature of the shadow is usually such as to define the difference.

In such cases the thorax must be viewed and radiographed in the right anterior oblique position, which is explained in diagnosis of aneurysm as described in the following section.

The heart and great vessels are projected in the median shadow seen in all views of the thorax. For description of this median shadow we refer the reader back to p. 189, and for its normal appearance to Fig. 105. The accompanying diagram (Fig. 109) recalls its form, and indicates the structures producing it.

The outline is most distinct on deep inspiration, due to the stronger contrast of the expanded lung tissue.

Concerning the heart itself, much may be learned directly and indirectly by noting changes in position, form, and relative dimensions of the shadow.

Enlargement of the organ may thus be diagnosed, and

possibly ascribed to one or other of its compartments, though with some hesitancy.

To differentiate in such enlargement between hypertrophy and dilatation—as we have seen done, at least in print—seems to us like making a laughing-stock of the subject.

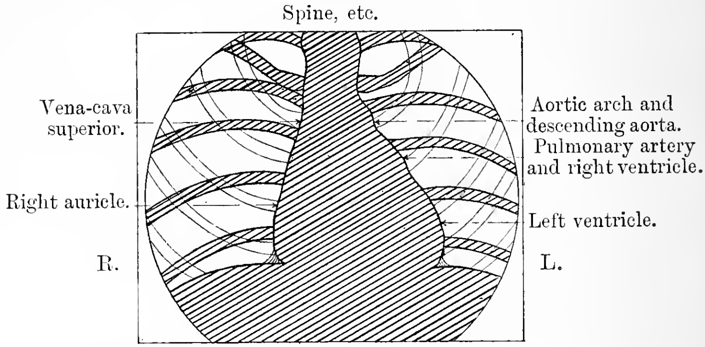


Fig. 109.—Sketch of Normal Cardiac Shadow.

Displacements have been discussed relative to their causative conditions in the preceding sections, and can certainly be more accurately estimated in most cases by X-ray examination than by percussion.

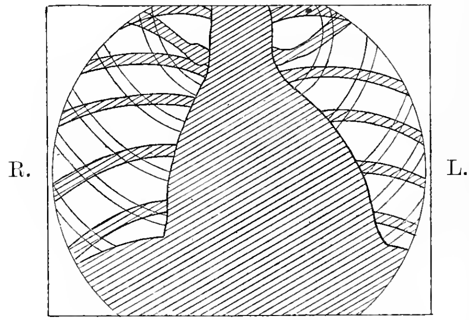


Fig. 110.—Sketch of Shadow in Pericarditis.

For measurement of dimensions we must have recourse to orthodiagraphy as described in the following chapter.

Pericarditis, if accompanied by fluid effusion, will be evidenced by marked increase in the area of the cardiac

shadow, which assumes a rounded appearance, in contrast to the typical form described. The extent of this will, of course, depend upon the amount of fluid present in the pericardial sac. The cardio-phrenic space will here be obliterated, and the

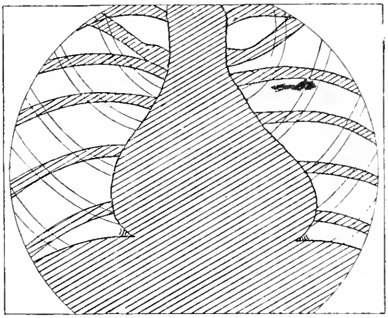
R.  L.

Fig. 111.—Sketch of Shadow in Mitral Stenosis.

R.  L.

Fig. 112.—Radiogram of Mediastinal Tumour.

pulsation usually seen at the left border will be diminished or abolished. Fig. 110 represents the form of the median shadow in pericarditis with a moderate amount of fluid.

Mitral stenosis produces a characteristic form of the cardiac shadow, due doubtless to the enlargement of the right

side added to that of the left. The form of the shadow, as seen from annexed sketch (Fig. 111), resembles that of a purse, and is so described.

Mediastinal tumour alters the form of the median shadow more towards its upper part, as shewn in Fig. 112.

This must be distinguished from the appearance of aneurysm as described in the following section. For this differentiation it is always advisable to view the thorax in the right lateral

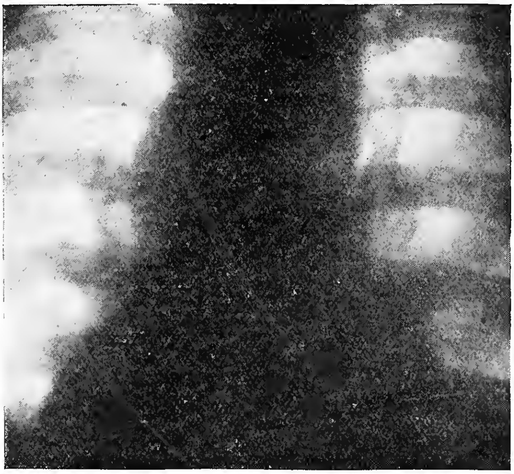
R.  L.

Fig. 113.—Radiogram of Aneurysm.

oblique position hereafter referred to. As a general rule, the alteration produced by a mediastinal tumour is less regular and distinct than that produced by an aneurysm.

Thoracic aneurysm can usually be detected in alteration of the median shadow as a bulging to one or both sides of its upper part, about the level designated as the left aortic bulge. The extra shadow is usually bounded by a well-defined rounded border, which may or may not show pulsation. That the emphasis put on this latter sign as pathognomonic of aneurysm is a mistake is borne out by X-ray examinations, for in many undoubted cases no special pulsation is seen. No reliance, then, need be placed on this sign.

The heart shadow so frequently assumes a more transverse position, with displacement downwards, that the appearance has come to be quite definitely suggestive of aneurysm. Specially in aneurysm of the ascending arch does this seem to be marked. In Fig. 113, which represents an aneurysm of the ascending arch, the alteration in position of the heart is well marked. When the abnormal shadow is chiefly to the right side, and fairly low down, we may diagnose aneurysm of the ascending aorta; when the shadow is higher up, and on

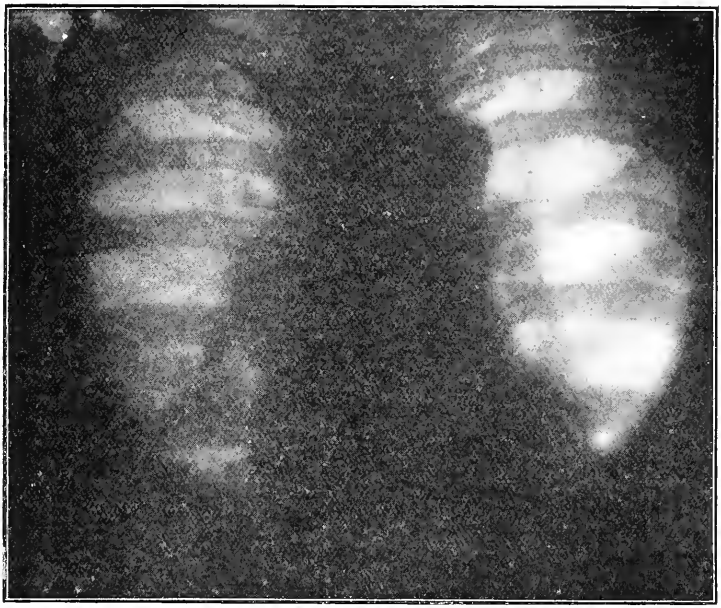


FIG. 114.—ANEURYSM OF TRANSVERSE ARCH OF AORTA.

both sides, we may locate it to the transverse arch (as in Fig. 114); and when lower down, to the left side, we may locate it to the descending part of the aortic arch. This indication is mainly relative, but usually distinct enough to satisfy practical requirements.

Quite recently we secured two interesting radiograms, reproduced in Figs. 114 and 115.

From the appearance of Fig. 114 we diagnosed an aneurysm

of the transverse arch of the aorta. This diagnosis was accepted by the hospital physician, although he assured us that the condition had given rise to no diagnostic symptoms whatever, leaving him quite puzzled as to its real origin.

At a subsequent meeting of a clinical society he expressed his hearty appreciation of the valuable assistance rendered by radiography in such a case.

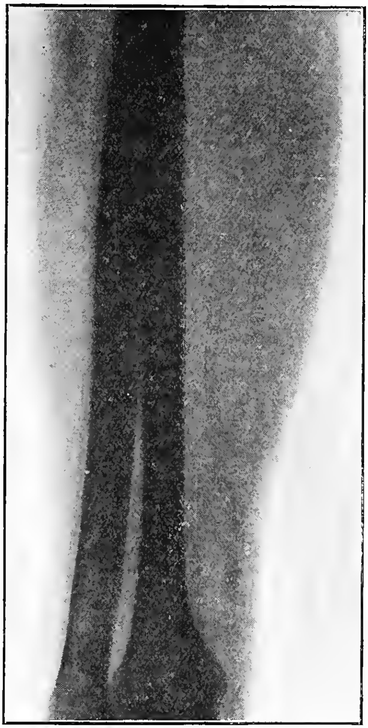


Fig. 115.—Radiogram, shewing Arteries during Life.

From the same patient we obtained the unique radiogram reproduced in Fig. 115.

There may be seen distinct shadows of the tortuous radial and ulnar arteries, made opaque by an excessive calcification of their walls. This was obtained by use of a very soft tube.

We have not seen reported any previous instance of arteries being distinctly recognisable in a radiogram of a living subject.

The shadow seen in the posterior or anterior position of screen or radiogram is a much exaggerated and distorted view of the aneurysm, and the degree of distortion will depend on the situation of the swelling in the thorax, hence comparison of size is made very difficult.

For this reason the orthodiagraph (as described in the following chapter) is of great value in estimating the true dimension of the aneurysm as recorded by its shadow, and for noting its progress.

More useful still, however, is the right anterior oblique position of exposure, first described by Holzknecht about 1901, which serves to differentiate aneurysm from other conditions causing similar forms of shadow.

The right anterior oblique position indicates a method of viewing the thorax whereby the constituents of the median shadow seen in anterior or posterior views are separated up to some extent. By placing the X-ray tube to the left of the spinal column behind, and about the level of the sixth dorsal vertebra, rays may be passed between the lateral fronts of the vertebræ and the descending aorta, so as to shew on a screen placed to the right of the mid-line in front a narrow, clear space bounded by two parallel shadows.

In this position the shadow of the descending aorta will be superimposed on that of the ascending arch, merging lower into that of the heart. Fig. 116, accompanying this, shews diagrammatically this arrangement, and explains better than words the result. The usual directions given are to place the tube and screen in a line making angles of 45° with the axis of the body, but this seems to us incorrect. As will be seen from the diagram—the body section of which is traced from Quain's 'Anatomy'—the position required is more nearly in a line making an angle of 30° with the dorso-ventral axis, and this will be found in practice to be more nearly the correct angle for a clear view.

Unfortunately a radiogram taken in this position is somewhat indistinct and difficult to reproduce in printed illustration,

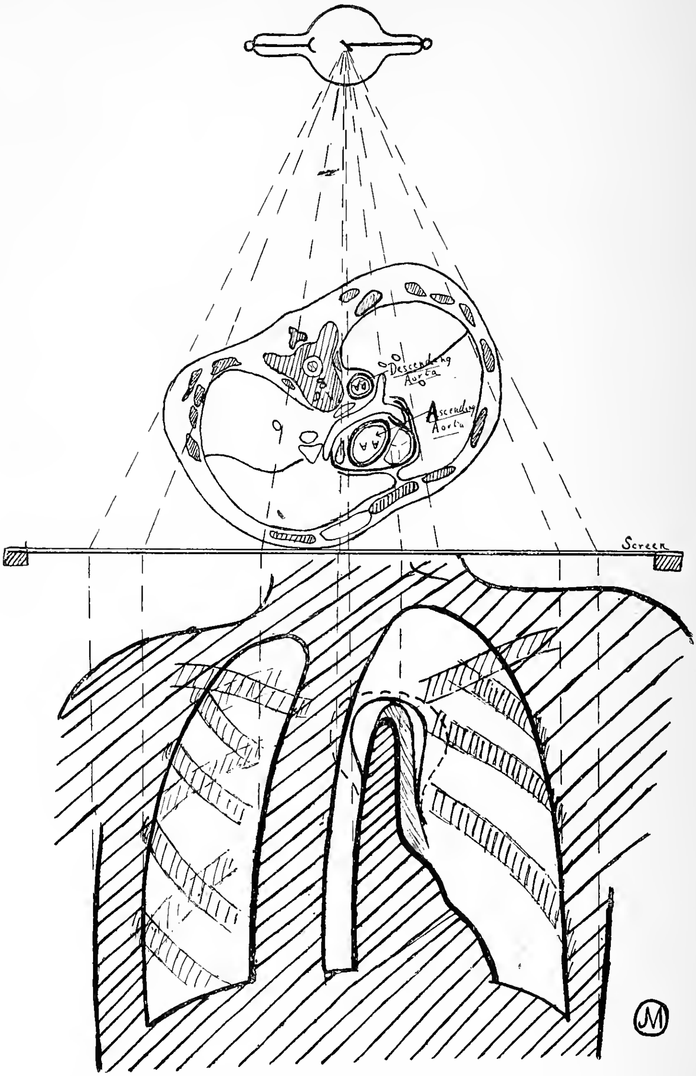


Fig. 116.—Sketch of Right Anterior Oblique Position and Projected Shadow.

so we prefer to base our description on the diagrammatic appearance shewn in the lower part of our sketch (Fig. 116).

This is shewn as projected on a screen placed in front of the thorax, which is above shewn in section through the eighth dorsal vertebra.

To either side are clear areas corresponding to lung, and centrally there is a narrow clear area, bounded on one side by a parallel-sided shadow of the vertebral column, and on the other side by a shadow, roughly triangular in form, produced by the superimposed parts of the aortic arch and, lower down, by the heart.

The upper end of this triangular shadow is rounded, and normally has parallel sides for some distance from the top till it merges into the cardiac shadow, ending on that of the diaphragm. This normal form is indicated by the heavy line continuous with the cardiac outline in the figure.

It is to the rounded upper end of this 'aortic shadow band' that attention should be paid. Even a very small aneurysmal swelling anywhere on the aortic arch produces a notable change in this, causing the end to become club-shaped, as shewn by the thinner line surrounding an unshaded area in the figure. The size of the club-head shadow will depend on the size of the aneurysm, a larger size being shewn in broken line, which reaches partly across the clear left lung area, and encroaches also on the vertebral shadow. Only one form of aneurysm can fail to reveal itself in this shadow, and that a rare one—namely, one forming on the bottom side of the transverse arch, and projecting downwards between the ascending and descending arches.

From a **generally dilated aorta** this view will also serve to differentiate an aneurysm, for the former condition will produce a shadow band of greater width, but still with parallel sides, as shewn by area of lighter shading in Fig. 116. Such a condition would nevertheless produce a marked broadening in the aortic region of the antero-posterior shadow, and might be very misleading, hence the value of this additional position may be understood.

Slight irregularities in the 'aortic shadow band' may be produced by other conditions than aneurysm, but in no other condition is the marked clubbing due to aneurysm reproduced. If the aneurysm be situated low down on the ascending arch

of the aorta, the rounded club-head may be situated lower down on the band and tail off towards the top end.

Fig. 117 (after Holzknecht) contrasts the appearances of antero-posterior shadows of certain conditions with those of the same conditions viewed in this oblique position, and shews how possible errors from the former view may be avoided by combining with it the latter.

The figure is self-explanatory.

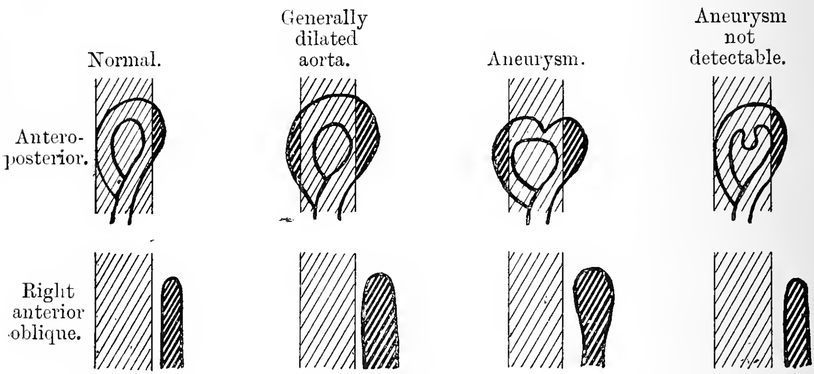


Fig. 117.—Sketch of Aortic Shadows as in Antero-Posterior and Right Anterior Oblique Positions of Screen.

A left posterior oblique position of the screen may be adopted with advantage for observing the **œsophagus** while opaque boluses or bougies are passed along it to detect stricture, diverticula, or other condition. This position is adapted from the foregoing one by substituting the tube and screen for each other.

CHAPTER IX

ORTHODIAGRAPHY

In examination of the thorax to determine the presence of cardiac dilatation, aneurysm, or a few other conditions, the indication of which depends upon noticeable change in the median shadow already described, a more exact record is desirable than that obtained by ordinary radiography.

In earlier chapters it has been pointed out that the shadow cast upon a fluorescent screen, or the image impressed upon a sensitive plate, is not a reliable index of the dimensions of the object interposed between the X-ray tube and the screen or plate. Due to the divergent character of the radiation proceeding from the antikathode, we obtain a magnified view of the object, the degree of magnification depending upon the distance of the object from the tube, and from the screen or plate.

As seen in Fig. 118, where A B and C D are of equal length, the magnification is greater as the object is nearer to the tube; the tube, for that reason, should always be at some distance from the object. (See also note on 'Teleradiography' on p. 219.)

But, as explained in the section on 'Photography,' the intensity of radiation, and consequently its effects, diminishes as the square of the distance. Thus the distance between tube and object is limited, and a distance of compromise is fixed upon, as explained in the section referred to.

Where the part exposed is such that the screen or plate can be placed close to the object casting the shadow, this factor of magnification may be practically ignored, as in radiograms of the bones of a limb, and as shewn at S′ S′ in Fig. 118. But

where the screen or plate can only be placed in position at some considerable distance from the object which intercepts the radiation, then, as shewn at S S in Fig. 118, the magnification demands attention, or may lead to difficulty and confusion in interpretation of the radiogram.

Distortion of form and of relative position of objects is also produced by the same fact of divergent radiation, where different points of the same object, or of adjoining objects, are not equidistant from the point of origin of the rays. Such is the condition of affairs in radiographing the thorax, and the median shadow is thus a magnified and distorted image of the objects producing it. Thus a heart-apex, correctly

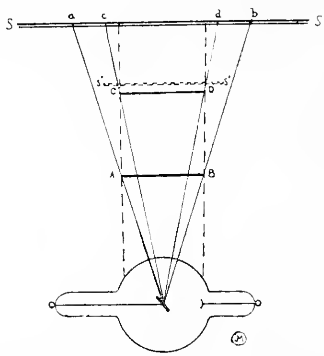


Fig. 118.—Sketch, shewing Central Projection.

defined by percussion as lying behind the fifth intercostal space, when viewed by a tube set behind the central point of the thorax, may have its shadow appear as in the eighth or ninth space.

Description of Method.—Orthodiagraphy is a recent method whereby this misleading element of magnification and distortion is eliminated, and a record obtained of the true dimensions in one plane of objects exposed. The principle is that of using only the central ray, or bundle of parallel rays, which proceeds from the antikathode in a line perpendicular to the desired plane. By movement of the tube this 'normal incident ray' is made to follow the outline of the object exposed, so as to cast on the screen a tangential shadow of

each point; then a tracing of this path of movement of the tube gives the desired record.

This will be understood more readily from a description of the actual process.

Several special arrangements of apparatus, more or less complicated, have been designed for the purpose of this

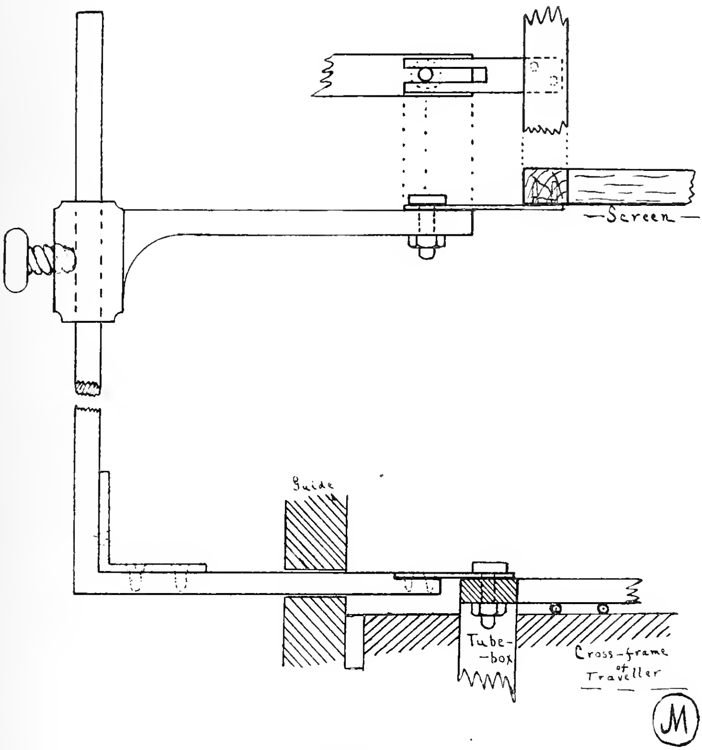


Fig. 119.

method, but the principle is alike in all, and the variations are solely in mechanical design for convenience of working. We will therefore confine our description to the adaptation we have made of the X-ray table already described on p. 89.

There we described a side-link, which we here shew in Fig. 119, by which the fluorescent screen, supported horizontally on the upper frame of the table, may be moved

synchronously with the X-ray tube below. Thus, if the point of impingement of the normal incident ray on the screen be marked, the orthographic shadow may readily be traced out. On the back of the screen are stretched two fine wires, joining the middle points of opposite sides, and crossing at the centre of the screen.

Close above the tube are stretched two similar wires, crossing opposite the central point of the diaphragm, exactly beneath which the focal point—or rather area—of the tube should be set. With all centred properly, the respective shadows on the screen of the two sets of cross-wires will coincide, but to attain this usually requires special adjustment.

For adjustment before use for orthodiascopy, set the screen in the centre of the space of the horizontal top of the carrier frame. Being fitted between transverse slides, this position relative to the length of the table is fixed, while laterally the centre is marked on the scale printed on one of the transverse bars. Set the tube-box also in the middle of its transverse path, and tighten up the screw that binds the screen to the upper horizontal arm of the side-link, the lower horizontal being already fixed to the tube-box.

Then close the diaphragm to its smallest, or nearly so, and send a small current through the tube sufficient to illuminate the screen.

Note on the screen the relative position of the magnified shadow of the lower cross-wires to the more sharply defined shadow of the wires affixed close to the screen, and adjust the tube in its supports till the points of crossing coincide.

This sometimes involves a little trouble, but with practice need not take very long, and one setting, if undisturbed, will, of course, serve for all subsequent work. If desired for clearness, the lower wires may be carried on a small frame fitting into slides, so that it may be removed after setting is completed.

With an object now interposed between the tube and screen, and the point of crossing of the wires set opposite any point of the outline of the shadow, it will be seen that this point on the screen is the perpendicular projection on the plane of the screen of the corresponding point of the object.

This is illustrated in Fig. 120, and from that it will readily be seen that the distance *a b* will correctly indicate the dimension of the object from A to B in the horizontal plane.

If a series of points of any object be thus projected, and the points of projection be suitably registered and joined up, a projection of the object relative to the plane of the screen will be obtained, and exact measurement may be made from

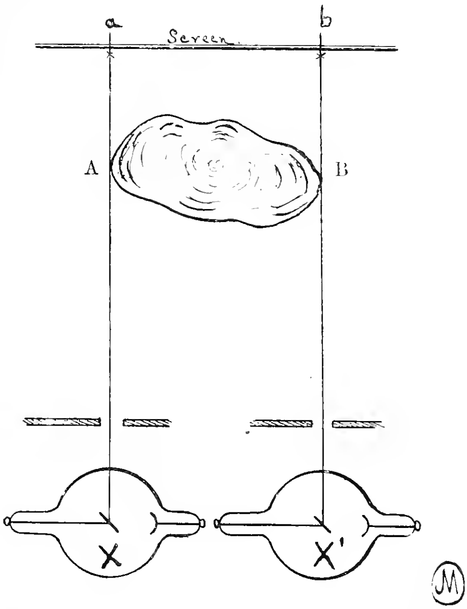


FIG. 120.—SKETCH SHEWING PARALLEL PROJECTION.

it. It is better to proceed by marking a series of points, and then joining those up, than to attempt to trace a consecutive outline in one process.

To register those points, the usual method adopted is to travel the point of incidence of the central ray (as indicated by the crossing of the wires described above, or by some other suitable contrivance) around the shadow outline, and let its path be traced, or points marked, by some means on a paper fixed parallel to the plane of the screen. This usually demands special apparatus, but we have achieved the same end by

adopting a method requiring only a small addition to the usual table described.

To the tube-box under the table we have fixed at a suitable point a small pneumatic plunger, with a blunted point at its lower end. This is connected by a rubber tube to a bulb, by squeezing which in the hand the plunger is propelled downwards to strike a flat board laid on the floor. A rubber band or spring restores the plunger to its former position. If on

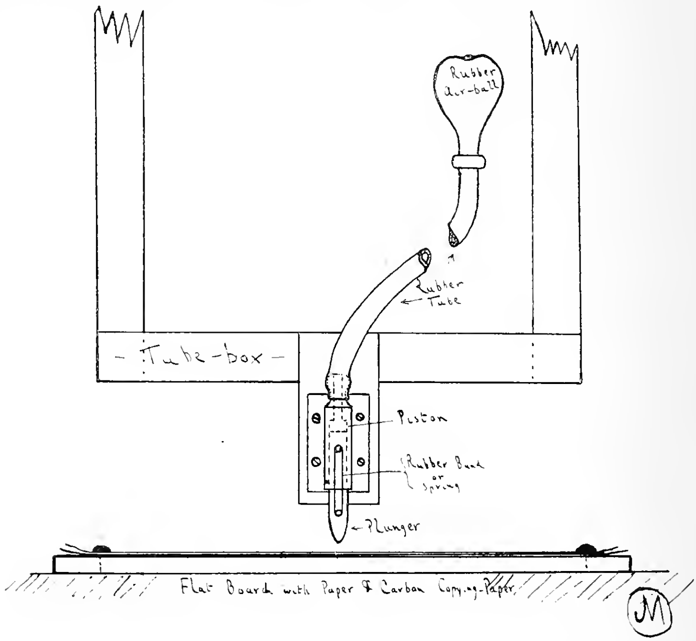


Fig. 121.—Mechanism for registering Orthodiagraphic Tracing.

the board be laid a piece of white paper covered by a piece of carbon copying-paper, each descent of the plunger is marked by a spot on the white paper, and the position of the tube-box is thus registered. This arrangement is shewn in Fig. 121.

Suppose a patient on the table ready for examination, and the tube centred as directed. Set the crossing of the wires about the centre of the area of which it is desired to trace the outline. Place the board, having papers fastened to it to receive the record, so that its centre is opposite the marking-

point, and all is ready for a start. Set the shadow of the wire crossing to a definite point of the shadow outline (in the usual median shadow such a point is one of the angles at the junction of heart and diaphragm), and make a mark by squeezing the bulb; then move the crossing to a point farther along that side of the shadow, set it exactly on the edge of the shadow, and make another mark. As in percussion, proceed from the clearer lung area towards the edge of the shadow. So proceed round the shadow, regulating the distance between points marked according to the regularity of the connecting outline, so that by joining up the marks a fairly accurate representation will be obtained of the outline traced. A few ribs should also be denoted as landmarks, along with the centres of the sternal notch and ensiform process to denote the middle line.

By this means we have traced outlines of inanimate objects, and measured them to the sixteenth part of an inch, while the heart can be thus more accurately measured than by percussion or in the post-mortem condition. For certain purposes it may be desirable to secure such a record with the patient in the erect posture, and this can also be readily done.

If the principle of the process be grasped, there will be no difficulty in conceiving how the same may be applied in an upright position. The whole difference is a question of mechanical arrangement, so we need not enter upon it here.

Our arrangement here described for recording the orthodiascopic outline of the heart and mediastinal contents has been criticised on the ground that it is not accurate. We admit that it is not accurate to a hair's-breadth of measurement, but it is in all respects virtually correct. When the thoracic organs are set mathematically in each person, then we will withdraw our method and bow to the dictation of the instrument-maker, but not till then. We thoroughly appreciate the necessity for precision in all diagnostic observations, but we fail to see the service of registering in fractions of a millimetre an outline which we know may vary by several millimetres, due to other causes quite beyond our control.

Thus, even if a patient be made thoroughly immobile, we cannot control or regulate his respiratory or cardiac movements.

Full inspiration, full expiration, complete systole, complete diastole, are not mathematical points cyclically reached under the most favourable circumstances, nor can any observer be depended upon to record the attainment of each limit of movement with even the comparative accuracy of the natural process.

Hence it seems to us decidedly foolish to discount a method which from its simplicity is universally applicable, while its accuracy is more than sufficient for the relative measurements on which alone a common-sense deduction will be based.

Where cost is of no consideration, and where part of the purpose of an installation is to impress the uninitiated, there may be admitted precedence for an elaborate orthodiagraphic apparatus; but where straightforward and reliable work is the sole object, then we are convinced, from a full experience of it, that the method we have described is in all respects sufficient.

The more elaborate designs may be more convenient for intermittent use, since they are separate and independent from the arrangements for ordinary radiography, but that in no wise affects the question of efficiency of results.

Apart from that question, the method we have adopted serves well to illustrate the principle of orthodiagraphy, and that is the main purpose of its description here.

Applications of Method.—By means of this orthodiagraphic method an exact record may be obtained of the form and movements of the thoracic viscera.

Thus, the position of the ribs and of the diaphragm may be registered at completion of inspiration and expiration in various types of breathing. The excursion of the two sides of the diaphragm from such record may be accurately compared, and inferences may be drawn from that and other data, as described in the preceding chapter (p. 190).

The true form of the median shadow is also obtained, the normal appearance of which is represented, as so traced, in Fig. 122. The general form, and the structures producing it, correspond to those described for a normal radiogram on p. 189; the latter are marked on the figure opposite.

Through such an outline, when obtained as described in

preceding paragraphs, the mid-line of the body should be drawn, and to that perpendiculars should be drawn on either side from the two most distant points of the outline. These perpendiculars are termed respectively the right and left 'median distance,' and together measure the 'transverse dimension' of the heart. Other lines are suggested to measure the 'longitudinal diameter' of the organ, and to indicate its inclination to the vertical axis of the body, but for practical purposes the two shewn in Fig. 122 are all we deem desirable.

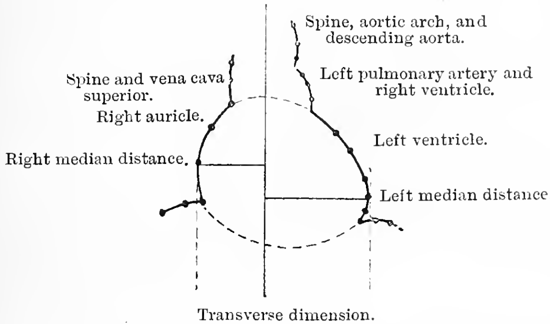


Fig. 122.—Sketch of Orthodiagraphic Shadow of Heart.

This transverse dimension is in most cases less than the greatest diameter of the heart, since the plane of that does not lie parallel to the transverse axis in which the screen is placed.

But absolute dimension is not really the criterion aimed at; so long as we obtain records relative to one plane, and therefore comparable with each other, the method fully satisfies diagnostic requirements. In normal hearts, or hearts with right-sided enlargements, the greatest diameter is always approximately in the same plane. With much dilatation of the left side the heart may be rotated and the plane altered somewhat, but ere that occurs the enlargement will be relatively unmistakable, though the tracing may record it as absolutely less than it actually is.

Hence the records obtained in all cases may be relied upon to indicate comparable dimensions.

As to the position of the patient during examination—erect or recumbent—there is some discussion. In the erect posture the heart lengthens and narrows perceptibly, there being probably also an actual decrease in volume as compared with the recumbent posture. Thus, records in either position must not be compared or confounded with records in the other, and note should be made on each record of the position of the patient during its production.

Between the two positions there is no very strong reason for preference. The erect posture is somewhat difficult to maintain steadily, for if the patient be seated there is some restriction of diaphragmatic movement, and if he stand he must be steadied by axillary supports, which also may affect respiratory movements. Hence, for fixation of parts and convenience of working, the recumbent posture is preferable.

The slightly greater volume of the heart in that position also causes us to favour it, and latterly we have made practically all our examinations in that posture. Against it is quoted a slight decrease in transradiancy of the lungs, making the shadow outline less distinct, but this is not a serious drawback.

Respiration affects the form of the cardiac outline somewhat, inspiration causing a slight narrowing, similar to the effect of the erect posture. The clearer lung area in that phase renders the outline more defined and more easily marked; hence the record may be made while the patient holds successive deep inspirations. Otherwise the middle phase of respiration is usually chosen as a safe average.

As to the heart itself, so little change is produced in the outline by the pulsations that there seems no necessity to insist on a special period for marking each point. That would, indeed, in many cases be quite impracticable, and always difficult. Because of the longer duration of diastole, probably most records are made in that phase, and this should be aimed at if any cognisance be taken of the point.

Of actual dimensions few tables have yet been published, and those few shew considerable range of variation in the normal. Moritz quotes the average transverse dimension of

the heart, taken in the recumbent posture, as varying from 12·3 cm. to 13·4 cm. (about $4\frac{3}{4}$ to $5\frac{1}{4}$ inches).

Williams gives the average width as 11·2 cm. for women and 11·6 cm. for men (about $4\frac{1}{2}$ and $4\frac{5}{8}$ inches).

The orthodiascopic outline will shew characteristic changes, due to aneurysm or other pathological condition of its constituents. These changes will correspond more or less closely to those already described in radiograms of the various conditions. We need not recapitulate them here, as this method does not aid in their differentiation, though giving a more exact record of the form of their shadows.

As a means of noting the progress of any enlargement of the shadow orthodiagraphic projection is of great service, and as we gain greater experience of its use and records, it will probably prove of still greater value as a method of precision.

It seems to us possible that the method might be applied to determine pelvic measurements, but we do not know of it having yet been so tried.

Teleradiography.

Teleradiography, a recent development in X-ray practice, promises in a more direct, though less exact, manner to eliminate much of the objection quoted in the opening of this chapter as being met by orthodiagraphy.

By the use of a current of very high intensity with an X-ray tube suitable for such current it is found possible to produce radiograms of the thorax with the tube set at a considerable distance from the sensitive plate—usually 80 inches (or 2 metres).

Thus, the distortion and magnification referred to on p. 209 is minimised, and a fairly exact record of the thoracic contents registered.

The time of exposure is normally one second or less with such an arrangement; no tube presently made could bear the current longer.

This brevity of exposure further conduces to clearness of

outline, the blurring effect of physiological movement being practically removed.

In this country and in America much work is presently being done towards making this process more practicable, and in a short time we hope to see methods devised such as to discount our objections stated earlier on p. 103.

At the sectional meetings of the British Medical Association at Sheffield an interesting discussion on this took place, and the present position may be well gauged from the report of those meetings in the *British Medical Journal* for September 12, 1908.

An interesting article on the application of this method to the study of gastric and intestinal movements appears in the *Archives of the Roentgen Ray* for October, 1908, and there are reproduced two remarkable radiograms resulting from exposures of only one-half second.

CHAPTER X

THERAPEUTICS

So far in this work we could dare to be dogmatic, for experience has to a large extent built up reliable rules, and differences of opinion amongst workers affect usually but questions of detail. But when we essay to write of the therapeutic effects of X rays we are on less sure ground. Much has been written on the subject, and much has been claimed, wisely and unwisely.

It is the misfortune of all new methods in therapeutics to be at first boomed beyond credence, and in the natural recoil of opinion a method may lose even that degree of credit it deserves. X-ray treatment is threatened with that fate, partly because of the reason stated, and partly because its nature has tempted many to apply it who are totally incompetent to observe or regulate its effects on tissues or processes, physiological or pathological. From this latter source of danger a number of culpable accidents have done much to rescue it. On the other hand, we trust a scientific moderation on the part of its advocates will gradually enable X-ray application to be confidently established as a valuable part of our therapeutic armamentarium.

There are many conditions which are undoubtedly benefited by X-ray treatment. Some of those conditions receive from such treatment so much more, or much more rapid, benefit than from any other known treatment, that X-ray application is adopted by choice. Certain other conditions are benefited by X rays, but results obtained are in no marked degree

superior to those obtained from other recognised treatment; hence the choice of treatment in such cases is indicated by secondary circumstances. Other conditions may derive benefit from X rays, but under ordinary circumstances are more amenable to other treatment; hence in these conditions X rays are only justifiably employed where special circumstances render other treatment inapplicable or ineffective.

Into the third class fall many of the long list of conditions too often quoted as 'having received benefit' from application of X rays. Knowledge of, and comparison with, the results obtained from other methods of treatment would exclude those conditions from the special ground claimed by the radiologist, who, in common with other specialists, is too apt to consider 'all fish that comes to his net.' Otherwise the general practitioner, disappointed in the comparative results of a few such treatments indiscreetly undertaken, may be excused when he makes a wholesale condemnation of the agent employed, even though he base his opinion on insufficient evidence. Apart from such conditions, however, there is a large and very important field in which X-ray treatment so far holds first place.

The general or special effect of X rays on tissues, physiological or pathological, or on the system, is not yet decided or explained in any satisfactory way, despite much valuable work on the subject. In a general way they may be said to set up a reaction in the exposed tissues akin to that indefinitely classed as inflammation. This effect on the skin, where it is most marked, is discussed later (p. 226), and is remarkable for its lateness of appearance and persistence. The action may go on to the destruction of normal tissue, as described later under 'Dermatitis' (p. 227), but may be controlled by regulation of the exposure. Short of such destruction of tissue, large dosage may produce epilation (p. 231) and atrophy of other skin appendages.

Towards pathological deposits and formations there would seem to be almost a selective action. This is what we find, however, in ordinary phagocytosis, and probably the X rays act merely as a suitable stimulant to that process. Some observers ascribe direct action to the rays, since disappear-

ance of neoplasm cells has been noted without any apparent inflammatory reaction ; but on this point further observation seems necessary.

Whether X rays have any direct effect on micro-organisms in the tissues is another unsettled question ; but, unless in very superficial affections, we can hardly suppose them to have direct destructive action, and probably their effect is indirect, and due to reflex phagocytosis. Observations of the opsonic indices during X-ray treatment of some bacterial affections should prove highly interesting and instructive, and might also serve as a useful guide in the regulation of treatment, but so far we are not aware of any such observations having been recorded.

The action of X rays in dispelling pain is indefinite, but none the less remarkable—in some cases astonishing. Especially is it valuable in cutaneous irritation, such as pruritus. Direct action on the nerve cells is ascribed to the rays by some observers, but here also the results hardly justify the claim. Thus the effect is most notable in peripheral affections, which tends to the conclusion that the action is due to hyperæmia produced without irritative disturbance of the surfaces affected.

Under the headings of various disease processes further remarks will be found on the action of X rays on the tissues and morbid products, for which we would refer the reader to subsequent paragraphs.

Before discussing the conditions in which X rays may be beneficially applied, we consider some details of the method and regulation of their application. It is especially to this aspect of the problem we devote our attention throughout this book, since we realise that in most other respects the X-ray worker must build up his own experience.

Dosage.—No empirical rule can be laid down to regulate dosage, but in all cases the treatment must be indicated by the result desired, and regulated according to the effects produced. In this latter relation we wish to direct particular attention to an observed fact of which little, if any, mention has so far been made in text-books, but which fact it is

essentially important to bear in mind when considering the advisability of X-ray treatment for any special case. The observation is, that in treatment of all tumours, benign or malignant, or of other conditions which benefit from X-ray application, much better results are obtained when the pathological process is in a quiescent state or stage. At times, indeed, such a process, when acute, seems to be encouraged rather than checked by X-ray exposure, and it is probably always better to abstain from X-ray treatment of an acute process.

The effect of any X-ray exposure will depend upon four factors: (1) *Quality* of the X-ray tube; (2) strength of *current* employed; (3) *distance* between tube and part exposed; and (4) *duration* of exposure. The influence of (1) is explained below; the effect will vary directly as (2) and (4), and inversely as (3), those points having been explained in the chapter on 'Photography.'

1. A **fairly soft tube,** with equivalent spark of about 3 inches, should be chosen where effect is desired on the surface, as is usually the case. To affect glands or other deeper structures, a harder tube should be used, up to 6 inches. It must be remembered, when treating skin conditions, that the softer the tube is the more intense will be its action on the superficial tissues. Where a tube falls below a 2-inch spark, it is safer not to use it for therapeutic purposes, or only for very short exposures, since with such a tube a slightly prolonged exposure might produce undesirable effects, in the way of an X-ray burn, as described later.

2. **Strength of current** is directly under our control to some extent, and should be regulated according to the hardness of the tube employed, since that factor determines the amount of secondary current actually passing in the tube circuit. It is a good plan to fix on a medium strength for that current, and to regulate the primary current supplied to the coil, so that the secondary is kept at that strength as measured by a milliampèremeter in the tube circuit. Thus the variation in hardness of different tubes, or of the same tube from time to time, will be to some extent counterbalanced. We have no definite assurance that radiation from

tubes of different degrees of hardness will, even when thus regulated, have equal effect. The probability is that this is not so; hence it is well to work always with a tube of about the same hardness if comparison of results is to be relied upon. Pending more exact observations on the point, however, the plan mentioned supplies us with a safe standard for regular work, always, of course, controlled by careful observation of effects.

3. A convenient **distance** should be fixed upon for ordinary work, and all applications made at that distance. That most commonly fixed upon, and observed by us, is a distance of 6 inches, or 15 centimetres, from the antikathode of the tube to the area exposed. When a special treatment stand and shield is employed, this distance is regulated usually by funnel-shaped distance-pieces placed against the part, and these serve the further purpose of directing the rays (see p. 84). In exceptional cases, where a very widespread effect is desired from the exposure, the distance may be increased, and other factors varied proportionately.

4. **Duration of exposure** is, of course, wholly under our control, and is by many spoken of as equivalent to dosage. With the other above-mentioned factors remaining constant this is essentially true, but it must never be forgotten that those factors are in practice constantly varying. We have purposely placed consideration of those other factors before this, so as to impress the point, for in regulation of this factor we must make allowance for the variation in the others. Under normal conditions it is our custom, approved by experience, to use a tube of about 3-inch equivalent spark-gap, to set that at a distance of 6 inches (15 centimetres) from the part, to pass through it a current of 1 milliampère, and to make such an exposure for five minutes twice weekly. This we recommend as a standard to be followed, and from which, if necessary, exposures under varying conditions may be reckoned. The duration of exposure—or, rather, the dosage—must be varied according to the effect desired. We may take it that for most purposes it is desired to set up in the tissues a steady reaction sufficient to resist and arrest the pathological process in evidence, but not sufficient to affect

injuriously the normal tissues. Some valuable work has been done recently, and is being continued, to enable us to regulate X-ray dosage from the effects noted on the general metabolism of the patient. Thus, Hirschfeld notes a decrease in the excretion of purin bodies as the surest sign of beneficial effect of X-ray exposures in leukæmia. On similar lines Edsall and Pemberton (reported in the *American Journal of Medical Science* for March, 1907) describe the nature of a general toxic reaction sometimes following X-ray exposure. In such cases there seem to be liberated certain toxic products, and if, by reason of deficient elimination through the usual excretory channels, those are retained in the system, serious ill-effects may follow. As already mentioned, opsonic observations might prove very useful in regulating the period and dosage of therapeutic exposures. So far, however, none of those methods have led to practical results, and our regulation is largely empirical, guided by clinical experience and observation of the effect on superficial tissues. Where those only are affected this observation is usually a sufficient guide, but the periodic and continued effect of each exposure should in all cases be carefully watched. After a short interval, varying in different individuals from a few hours to two days, each application (after the first two or three) is followed by more or less hyperæmia of the part exposed, and possibly of surrounding parts. This effect should have disappeared before the next application is made, unless for any special reason it is desired to 'push' the treatment. Where it is seen to persist, it is in general better to postpone further application for a few days, and to shorten future exposures. If along with this persistent hyperæmia or erythema there should at any time appear œdema of the part or surrounding tissues, treatment must be stopped for at least a month, and a look-out kept meanwhile for a possible dermatitis or X-ray burn. This unfortunate effect is rarely met with in work carefully supervised by a competent operator, but the scare set up by its occasional occurrence in other hands has served a good turn in curtailing operations by unqualified and incompetent persons.

In certain cases a maximum effect is desired at one sitting.

This is practically confined to cases requiring epilation for their effective treatment, and will be discussed when such cases are considered in a later part of this chapter (see p. 232).

Dermatitis set up by X rays may be **acute** or **chronic** in its inception and course. The **acute** affection is practically confined to patients submitted to one exposure unduly prolonged, since its possibility by cumulative effect may, and should, be checked by ordinary care in procedure, as noted above. All single exposures of a series should be kept well within the margin of safety by regulation of the various factors mentioned; and when a maximum effect is desired from a single exposure, that should further be checked directly by the simultaneous and visible effect on a sensitised indicator, as described later. An unduly prolonged screen examination may expose the patient to a similar danger, or repeated radiographic exposures of any part, as mentioned on p. 98.

To observe proper precautions, one must, of course, know the condition and quality of the apparatus with which he is operating. The importance of this was borne in upon one of the writers by a mishap which befell him from use of a hired apparatus. Some time after exposure of a patient for fifteen minutes, at a distance of 6 inches from a tube, to which but a moderate current was supplied, he was surprised to find a bulla form at the part exposed. On subsequently testing the tube, which had been supplied as of medium hardness, he found an explanation in the fact that it had an equivalent spark-gap of only 1 inch, but the test, unfortunately, was at the wrong end of the programme.

After such an excessive exposure nothing abnormal may be noticeable for ten days or more; then lesions become evident, varying from severe, but temporary, erythema to formation of bullæ, and persistent and most intractable ulceration. Much is to be said for the opinion that 'X-ray burns' are caused by 'chemical rays' in the emanations from the tube, since there is striking analogy between the milder degrees of such and 'sunburn.' Thus in each, pigmentation is often marked, clothing seems to provide efficient

protection, and there is evidence of personal susceptibility, although Sabouraud states that the factor of idiosyncrasy may be neglected in X-ray work. But discussion of this would lead us beyond our present purpose. No specially successful treatment has been suggested for those undesirable effects, and some severe cases seem to baffle all treatment, but ordinary cases recover, though slowly, if treated on general lines with soothing and antiseptic dressings.

Chronic dermatitis is usually seen in X-ray workers on parts subjected to frequent, though relatively weak, exposures. Precautions advisable for prevention of this have been already discussed on p. 98. Earliest evidence of the condition is usually seen at the bases of the finger-nails, which in screen examinations are the most exposed part of the body. Here redness and dryness of the skin appears with some feeling of irritation, and gradually the white laminæ at the roots of the nails disappear. In the absence of precautions, all degrees of dermatitis may be produced by repeated exposures, this being proved in a most unfortunate manner on the persons of some early operators who were then unaware of the danger. But with due care further effects than those mentioned above ought to be readily prevented. Protection of the body generally, and of the testicles especially, should also be remembered. In the section on 'Accessory Apparatus,' at p. 84, is described a special stand with shield for protection of the operator and surrounding parts of the patient during exposures for therapeutic purposes. For further description of X-ray dermatitis we refer the reader to articles by Dr. Hall-Edwards in the *British Medical Journal* for October 15, 1904, and that of September 12, 1908, as also in the X-ray number of the *Practitioner*, published in 1906.

Conditions Suitable for X-Ray Treatment.

In detailing conditions in which X-ray treatment may be advocated as useful and commendable, we have carefully compared the results possible from such treatment with those obtained by other methods as known to us from experience of general practice. We trust that thus we may avoid the

overestimate of enthusiasm into which a too rigid specialisation is apt to lead. In each case our estimate is based on practical experience of our own work and that of others, and in no case do we express approval where experience impels us to doubt.

Lupus vulgaris is the affection in which the best results have been noted from application of X rays, and these results are such as to render this treatment preferable to all others. It is true that many cases respond to other measures, such as scraping and use of caustics accompanied by general treatment, but a large number of cases resist such treatment; whereas under the influence of X rays practically every case may be confidently expected to benefit, and most to be completely cured. As compared with treatment by the Finsen lamp, the factors of time and expense render X-ray treatment vastly superior. With a Finsen lamp only very small areas can be exposed at a time, and applications of one hour's duration are necessary on occasions, numbering possibly over a hundred. The apparatus, too, is very expensive to instal and to operate, so that on the whole we must deem the treatment quite superseded, though in so saying we detract nothing from the admirable work of the heroic man by whom it was instituted. In the **nodular** type Finsen treatment is more efficacious, but for the **hypertrophic** and **ulcerative** forms X rays should be used.

To X rays large areas may be exposed and treated at each sitting, which need last only for five minutes twice weekly; and marked benefit, and probably cure, may be looked for after a few months of such treatment. In treating an area of lupus it is well to include a fair margin of surrounding tissue in the exposure. In certain cases small spots remain in an area so treated, and on pressing a microscope-slide over such the typical apple-jelly-like appearance may be noted. Such spots of residual disease may be effectively dealt with by exposure to a Finsen lamp, which should clear them up after a few exposures. This avoids the further exposure of the larger area already healed, but the measure is seldom called for.

Recently fear has been expressed by a few workers that X-ray application to lupus has in some cases produced an epitheliomatous condition. But this condition has been noted as superimposed on lupus areas without application of X rays, and, in the absence of evidence indicating an increase in the incidence of this secondary condition in cases so treated, we cannot think that the fear is justified.

Tuberculous glands and ulceration are also benefited by X-ray treatment, and this should always be tried before resort is had to operation. **Glands in the neck** are markedly influenced, and the cosmetic result is, of course, preferable in avoidance of a scar.

Tubercular bone disease may receive marked benefit by X-ray exposure, but tubercular conditions affecting the viscera are probably little affected, if at all, by such treatment, though reports of isolated cases claim benefit from it.

In **lupus erythematosus** results are not so uniformly good; therefore the treatment should in such cases be used with caution.

Cancer.—Using this term in the broadest and most inclusive sense, we may say that, where the process is **superficial**, the effect of X-ray exposure is very marked, and cure follows in most of such cases. Where the process is **deep-seated**, we fear that revised diagnosis would dismiss most of the so-called 'cures' by X rays; though, as will be pointed out shortly, we believe that X-ray treatment is of undoubted service in malignant cases beyond the possibility of operation.

Rodent ulcer usually disappears after a comparatively brief treatment, ten to twelve X-ray exposures of five minutes each substituting for the ulcer a smooth, unobtrusive cicatrix.

Cutaneous epithelioma is influenced in a similar fashion, though results are not quite so uniformly successful.

Paget's disease, if uncomplicated by involvement of the ducts and gland, may be cured by exposure to X rays; but we should hesitate to undertake a treatment unless operation were refused or impossible.

For **deep-seated malignant tumours** X rays cannot be pronounced a cure, and in our opinion operation should never be refused nor delayed for such treatment. Where, however, operation may be refused by the patient, or where, for some reason, radical operation is impossible, X-ray treatment should certainly be applied. The distressing symptoms of such cases are markedly relieved by occasional applications. So marked, indeed, is the apparent benefit that one is often tempted to believe that a cure is being effected. The pain lessens, the tumour decreases in size, nodes may heal up, and loss of weight may even be temporarily averted. The patient's life is probably prolonged, and is certainly made more comfortable; while the hope which the relief raises in his mind is good in itself, though it should not be unduly encouraged. After a time of such apparent benefit the end usually comes suddenly, but surely this is better than the long-drawn-out agony so often observed.

X-ray treatment seems to arrest such a process partially, but it looks as if something else were required to complete the cure, and for that it seems we must search elsewhere. Possibly, on the other hand, the apparent local benefit by way of absorption or dissociation of the neoplasm is accompanied by dissociation of toxic products, which eventually result in death.

For such treatment of deeply-seated tumours a moderately hard tube should be used, and the skin protected by some material, such as a piece of chamois-leather. Some workers use so-called 'filters' of heavy material, and give long exposures; but, through some of the materials employed we question if any considerable amount of radiation can reach the patient, and a thin layer of felt or chamois-leather is sufficient.

Epilation is an effect of X rays on which we may rely, and upon this effect depends its value in certain parasitic diseases

of the scalp or other hairy parts. For removal of superfluous hairs—so-called **hypertrichosis**—the treatment is not recommended, since in most cases hair grows again on the area epilated, unless, indeed, sloughing has been produced, when an ugly cicatrix will probably result. Repeated epilations will ultimately induce permanent alopecia, but the risks of pigmentation, or scarring, contra-indicate this method of treatment.

Tinea tonsurans, or Ringworm.—Mainly in connection with this obstinate disease have the conditions of epilation been studied; thus it is fitting that under this special heading we should describe the process, although it is equally applicable for any other condition demanding epilation.

A maximum effect is here desired with one exposure, and to measure the correct duration of that under prevailing conditions of tube and current, a **Sabouraud's pastille** is simultaneously exposed to the rays. The principle of this is described on p. 10, and will be dealt with later in this description of the operation.

Only the area affected should be exposed to the action of the rays, and the rest of the head must be protected by suitable means, the details of which will depend upon the form and extent of the area affected. Thus the head may be covered by a helmet of sheet-lead or other material opaque to the rays, in which holes are cut opposite to each part to be exposed. A better arrangement is that illustrated in Fig. 48 and described on p. 84. A funnel of appropriate size, being fixed in the shield there shewn, gives the correct distance for exposure as well. The area exposed must be large enough to include a fair margin of apparently healthy but possibly infected surface. Where the whole head is affected, exposure is best made in three applications at one sitting. This may be done by cutting from a sheet of lead a triangular sector, with a central angle of 120°. Mould the remainder over two-thirds of the head, and change its position between each exposure, so as to expose in turn three areas comprising the total superficies.

Preliminary preparation being completed as found suitable

for the case, set the tube—preferably by a fixed distance-piece—with its antikathode at a distance of 6 inches, or 15 centimetres, from the head. To check the exposure, a Sabouraud's pastille must be exposed to the free action of the rays at a point midway between the antikathode of the tube and the area exposed—that is, 3 inches, or $7\frac{1}{2}$ centimetres, from either. Various contrivances have been devised to support the pastille under proper conditions at this distance, but the best arrangement is the therapeutic shield already described. At one side of the brass ring forming the front opening of the shield will be found a brass disc, which is removable, being held in position by a small spring clip. In a hole in this is placed a pastille, and the disc, being inserted edgewise, bears the pastille so that it is exposed to the full action of the rays during exposure.

The **pastilles**, about $\frac{3}{8}$ inch in diameter, are usually supplied in a booklet, with some instructions for use. On the front page are two small plaques of paper coloured respectively of the tint of the original pastille and of the tint assumed by a pastille 'after exposure to X rays, corresponding to the maximum dose which the human scalp is capable of sustaining without being followed by erythema, radio-dermatitis, or permanent alopecia.' Directions are given to place the pastille on a metallic support—that is, with a metal backing—at half distance between antikathode and skin. Since the platino-cyanide resumes its original colour if exposed to daylight, directions are given that the examination of a pastille during exposure, and comparison of it with the standard tint, should be quickly done, so as to prevent daylight interfering with the action. After a few such comparisons, it will be noted that the colour of the pastille has changed to that of the standard. At this point the exposure may be considered complete, and the current switched off.

Under ordinary conditions the exposure averages from fifteen to twenty minutes. One might reasonably say that, if note were made of that time and those conditions, then by reproducing the conditions the time should be a good enough index of the current exposure. But, as we have already pointed out, we cannot rely upon exact reproduction of

the conditions, and no mechanical regulations so far devised can justify making a maximum exposure without some such direct check as we describe. It is stated by some workers that the pastilles after exposure regain their original colour and can be used again, but we prefer to use a fresh pastille for each exposure made.

About fifteen days after such an exposure—usually on the sixteenth day—the hairs will fall out from the area exposed, and with them, presumably, the parasites. During this interval it is customary to apply daily to the part and the surrounding parts some parasiticide, to prevent spread of the process meanwhile. For this purpose Sabouraud uses and recommends tincture of iodine 1 in 10 of rectified spirit. After epilation the head should be washed daily, and any weak hairs left should be pulled out. By the thirty-fifth day all hair should be out. Baldness remains for two months, and the head should return to its normal condition in about four months.

This is doubtless a radical cure for ringworm, and much in advance of older methods, so often tedious and disappointing. There is a slight danger of overexposure and burn, followed by permanent baldness; but this should not happen if proper care be taken. On the other hand, if the exposure be too short, then all the hair may not come out, and the process cannot be repeated till after twenty-one days from the first exposure; but this also should be of rare occurrence.

It is possible that this treatment, good as it undoubtedly is, may be replaced soon by another electrical method, probably more rapid, more safe, and less expensive. This method is by electrolysis or cataphoresis with chloride of zinc or sulphate of copper; but until the process is made more certain in operation we may consider X-ray application the best radical cure for ringworm.

Favus, Sycosis.—In a similar way to that described for ringworm, X rays may be beneficially used for favus, sycosis, and similar parasitic affections. Results quoted are very good, but of the treatment of either by this method we have little personal experience.

Pruritus ani, pruritus vulvæ, and **prurigo** are relieved by application of X rays in a rapid and effective manner difficult to explain, but none the less definite and valuable.

Keloid and multiple **warts** disappear under X-ray treatment in a remarkable manner; whilst **contracted scars** following operation, burns, or wounds benefit markedly from such exposure.

Leprosy is stated in reports from the Philippine Islands to respond in a promising manner to X-ray exposures. In a case we had the opportunity of treating for a time we noted distinct improvement of individual nodules. The lesions were, however, advanced and widespread, and the patient was very irregular in his attendance at hospital, so we had little chance of making reliable observations. In such an intractable condition, certainly, a thorough trial should be given to this form of treatment.

Eczema and **psoriasis** should not be exposed if in the acute form, but chronic cases derive marked benefit from careful X-ray treatment. Where the hands are affected by either condition, such treatment is especially useful; and the effect is very beneficial in eczema of the anus or genitals, accompanied by much irritation, though it may not be evident till after seven or eight days. Those and similar points are set out in a most instructive manner in a paper by H. E. Schmidt, which is quoted in the *British Medical Journal* for September 15, 1906.

In all recent works on dermatology X-ray treatment is discussed, and at least one text-book is published which deals solely with this subject; hence we do not consider it necessary nor advisable to enter further into detail of suitable cases and procedure.

Port-wine nævus is another condition so intractable that any safe treatment promising benefit should certainly have a trial. We have had one case recently under X-ray treatment with encouraging result, and a few cases are reported by

other workers where marked benefit has been obtained. Here a fairly severe reaction must be produced, requiring long intervals between the exposures, and special care to observe the residual effect of each previous reaction before superposing another.

Chronic ulcers defying ordinary treatment may respond to X-ray exposures; which remark may also apply to **acne vulgaris, acne rosacea**, and **alopecia areata.**

Favourable reports are published of similar benefit in certain conditions defying other treatment, such as **elephantiasis, ichthyosis**, and **mycosis fungoides.**

Exophthalmic goitre shews marked temporary improvement under treatment by X rays, but we have hitherto been disappointed with relapses whenever the treatment is discontinued. This seems to be the general experience, but the relief of symptoms obtained is often valuable.

In the **treatment of systemic disease** it is still more difficult to gauge the true position of X rays. Reports are conflicting, and many of them incomplete, whilst the effect of contemporary treatment is frequently not eliminated. Thus in most conditions a definite opinion must be withheld.

Leukæmia shews the least questionable results. In some cases, especially of the **lymphatic** form, the benefit received from X-ray treatment is certainly most remarkable where other treatment had failed. One such case of apparent cure is reported in the *Lancet* for June 29, 1907. **Spleno-medullary** forms also receive benefit from the treatment, the glands, spleen, and long bones being all exposed to the rays. Other reports state that the treatment is not uniformly favourable, but even the admitted percentage of good results is very satisfactory. Recently fear has been expressed of coincident damage done to the blood-forming organs by application of X rays in leukæmic conditions, and careful investigation is still required to place the treatment on a safe basis.

Lymphadenoma, or Hodgkin's disease, shews temporary benefit from exposure of the glands to X rays. We have seen a well-marked diminution induced in the size of the glands, with resultant relief to the symptoms and discomfort due to their pressure; but the benefit is probably but palliative and temporary, which is all one might expect from the nature of the affection.

In a case of **splenic anæmia** recently under treatment we noted a marked diminution in the size of the spleen, with relief of the accompanying discomfort. This was accompanied by a decided improvement in the blood-count; but unfortunately we unexpectedly lost trace of the patient.

This list of conditions amenable to X-ray treatment we do not assume to be exhaustive, and we have left much unsaid that might be of interest concerning the conditions mentioned. But we have selected typical diseases, and have noted all those in which benefit is generally admitted. Fuller discussion of such conditions, or inclusion of others, would lead us beyond the scope of our intention. We trust, however, that we have set down sufficient information to serve as a guide in practical work, and to indicate the lines along which further progress may be expected.

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THE END

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